Transactions of The New York Academy of Sciences

SERIES II
VOLUME 14

NEW YORK
PUBLISHED BY THE ACADEMY
1951—1952

Editor

ROY WALDO MINER

CONTENTS OF SERIES II, VOLUME 14

PAGE

Title page i
Contents iii
Thrust Faulting—What Does It Mean? *By* CHESTER R. LONGWELL 2
The Role of Information Theory in the Inactivation of Maxwell's Demon. *By* HOMER JACOBSON 6
Polarized Light Navigation by Arthropods. *By* TALBOT H. WATERMAN 11
Viruses and Cells—A Study in Tissue Culture Applications. *By* GEORGE O. GEY AND F. B. BANG 15
Some Current Views on the Origin of Pernicious Anemia and the Absorption of Vitamin B_{12}. *By* C. C. UNGLEY. 25
P-technique, A New Method for Analyzing the Structure of Personal Motivation. *By* RAYMOND B. CATTELL. . 29
Elementary L_1-Spaces. *By* L. A. MACCOLL 35
Cloud Seeding by Means of Dry Ice, Silver Iodide, and Sodium Chloride. *By* IRVING LANGMUIR 40
An Evaluation of the Technique of Cloud Seeding to Date. *By* FERGUSON HALL 45
The Isolation from Soil of Fungi Which Cause Disease in Man. *By* CHESTER W. EMMONS 51
Conferences Held:
"Influence of Hormones on Enzymes" 55
"Curare and Anti-Curare Agents" 55
"World Population Problems and Birth Controls" 56
New Members 57, 123, 142, 184, 215, 255, 298, 340
Elasticity and Constitution of the Earth's Interior. *By* FRANCIS BIRCH 72
Symposium on Intravenous Lipid Emulsions:
Intravenous Lipid Emulsions. *By* E. D. GOLDSMITH 77
Clinical Studies on Hepatic Function Following Administration of Intravenous Fat Emulsions. *By* W. B. WADDELL, T. B. VAN ITALLIE, R. P. GEYER, AND F. J. STARE 78
The Administration of Fat Emulsions in Man. *By* B. G. P. SHAFIROFF 80
The Localization of Particulate Fat in Injured Blood Vessels. *By* W. B. MCALLISTER AND L. L. WATERS. . 83
Problems in the Provision of Calories Parenterally. *By* SIDNEY C. WERNER 84
Aero-thermodynamic Phenomena in a Revolving Fluid Motion. *By* PAUL H. SAVET 86
Reading and Visual Work: A Contribution to the Technique of Experimentation on Human Fatigue. *By* LEONARD CARMICHAEL 94
Studies on Lignin and Lignification. *By* F. F. NORD AND GEORGE DE STEVENS 97
The Isolation of Plant Rusts Upon Artificial Media and Some Speculation on the Metabolism of Obligate Plant Parasites. *By* VICTOR M. CUTTER, JR. 103
Philosophical Anthropology and World Law. *By* F. S. C. NORTHROP 109
The General Circulation of the Lower Atmosphere. *By* SVERRE PETTERSSEN 113
Conferences Held:
"Microwave Spectroscopy" 120
"Viruses as Causative Agents in Cancer" 120
"Shock Syndrome" 122
Report of the Annual Meeting 126
Atomic Energy Comes of Age. *By* JOHN RAY DUNNING 134
Abstracts of Prize-Winning Papers:
Direct Evidence for the Multiplication of Aster-Yellow Virus in Its Insect Vector. *By* KARL MARAMOROSCH. 135
Studies on Cell Differentiation: Auxin as the Hormonal Factor Limiting the Differentiation of Xylem Cells Around a Wound. *By* WILLIAM P. JACOBS 136
New York Academy Prize Competitions for 1952 136
Symposium on Streptococcal Enzymes:
A Streptococcal Proteinase and Its Precursor. *By* STUART D. ELLIOT 137
Elaboration and Inhibition of Streptococcal Desoxyribonuclease. *By* ALAN W. BERNHEIMER 137
The Action of Streptococcal Desoxyribonuclease on Purulent Exudates. *By* SOL SHERRY 138
Conference Held:
"The Chick Embryo in Biological Research" 141
Tectonic Team-Research, Key to Social Progress and World Peace. *By* W. T. THOM, JR. 146
Thermal and Photodegradation of Vinyl Polymers. *By* ROBERT SIMHA 151

PAGE

Symposium on Bacterial Pyrogens:
Introduction. *By* FLORENCE B. SEIBERT 157
Activities of Certain Bacterial Polysaccharides. *By* W. F. WINDLE 159
Biology of Pyrogens. *By* PAUL A. ZAHL AND S. H. HUTNER 161
Streptococcal Hyaluronidase. *By* KARL MEYER 164
Influence of an Electric Field on an Electric Current in Metallic or Carbon Conductors. *By* OLEG YADOFF 165
Experimental Semantics. *By* GREGORY RAZRAN 171
Problems Associated with Extending the Time Range of Weather Prediction. *By* JEROME NAMIAS 177
The Excavations at Hotu Cave. *By* CARLETON S. COON 179
The New York Academy Prize Competitions for 1952 180
Conferences Held:
"Virus and Rickettsial Classification and Nomenclature" 181
"Use of Antibiotics in Tropical Diseases" 182
"Biology of the Testes" 183
Symposium on Phase Microscopy:
The Practical Theory of Phase Microscopy. *By* HAROLD OSTERBERG 190
Applications of Phase Microscopy in Cytology and Electron Micrography. *By* LEONARD ORNSTEIN AND ARTHUR W. POLLISTER 194
A Study of the Life Cycle of Spirochetes and Other Micro-Organisms by Means of Phase Contrast and Routine Microscopy. *By* E. D. DELAMATER 199
Some Basic Problems in Communication of Information. *By* LOFTI A. ZADEH 201
Minority Personality and Adjustment. *By* GERHART SAENGER 204
On the Zoological Position and the Evolutionary Significance of Australopithecines. *By* P. TEILHARD DE CHARDIN 208
A Survey of Mucorales. *By* C. W. HESSELTINE 210
Conference Held:
"Comparative Conditioned Neuroses in Human and Other Animals" 214
Geologic Structures in the Ethiopian Region of East Africa. *By* M. HALL TAYLOR 220
Cenozoic Volcanic Activity in Japan and Surrounding Areas. *By* HISASHI KUNO 225
Symposium on Viruses and Hemolytic Anemia:
Action of Viruses on Red Blood Cells. *By* BERNARD A. BRIODY 231
The Red Blood Cell as a Vehicle of Virus Transport: I. Isolation and Identification of Blood-Borne Viruses. II. Role of Blood-Borne Viruses in Autohemagglutination and in Hemolytic Anemia. *By* S. E. MOOLTEN AND ELLEN CLARK 232
A Critique on Our Knowledge of the Etiology of Hemolytic Anemia. *By* DANIEL STATS AND LOUIS R. WASSERMAN 238
The Diagnostic Memory Scale: I. Comparison of Brain-Damaged Patients and Normal Controls. *By* ROBERT S. MORROW AND JACOB COHEN 241
Scientific Developments in Industrial Engineering. *By* DAVID B. HERTZ 246
Context of Rebellion and Accommodation in Post-War Sicily. *By* VINCENZO PETRULLO 250
The Isolation and Differentiation of *Monilia* and Other Fungi. *By* GEORGE H. CHAPMAN 254
The Fractionation of the Serum Protein by Electrophoresis-Convection. *By* JOHN G. KIRKWOOD 260
The Physical-Chemical Approach to the Problems of Chemotherapy. *By* ALEXANDER V. TOLSTOOUHOV 260
Symposium on the Diamidines in Pharmacology and Clinical Application:
Pharmacology and Therapeutic Value of Diamidine Derivatives—Particularly of 2-Hydroxystilbamidine. *By* I. SNAPPER, B. SCHNEID, L. MCVAY, AND F. LIEBEN 269
The Use of the Aromatic Diamidines for the Treatment of Systemic Fungal Disease. *By* EMANUEL B. SCHOENBACH 272
Convection and Zonal Rotation in Celestial Bodies. *By* W. S. JARDETZKY 273
A Panel Discussion on Differences between Anxiety and Other Feelings:
Anxiety and Other Feelings. *By* HOWARD LIDDELL 276
Differences between Anxiety and Other Feelings. *By* PAUL H. HOCH 278
On the Psychoanalytic Exploration of Fear and Other Emotions. *By* SANDOR RADO 280
Some Problems Concerning the Dynamics of the Gulf Stream. *By* GERHARD NEUMANN 283
"Arctic Hysteria" and Latah in Mongolia. *By* DAVID F. ABERLE 291
Conference Held:
"Oral Fat Emulsions and Their Use in Medicine" 298
Is "Macroevolution" Reality? *By* DAVID M. S. WATSON 302

PAGE

The Release and Identification of Blood Borne Vasotropic Substances After Whole-Body Irradiation. *By* THOMAS J. HALEY 303

Symposium on Education in Biology—Its Perspectives and Horizons:

Biology for the Research Worker and Teacher. *By* WALTER H. WOLFF 306

Youth Movement in Biology. *By* WATSON DAVIS 308

Symposium on Studies on the Pancreas:

Physiology of the External Secretion of the Pancreas. *By* J. E. THOMAS 310

The Production of Experimental Lesions in the Pancreas. *By* M. WACHSTEIN 313

An Evaluation of Pancreatic-Function Tests in the Diagnosis of Pancreatic Disease. *By* DAVID A. DREILING, SR. 315

The Hyperglycemic Factor of the Pancreas. *By* I. J. PINCUS 319

Some Aspects in the Control of Air Pollution in Industrial Areas. *By* NICHOLAS V. FEODOROFF 321

Personality Characteristics of the Facially Disfigured. *By* THEODORA M. ABEL 325

Studies on Fungicidal Action Using Radioactive Tracers. *By* LAWRENCE P. MILLER AND S. E. A. MCCALLAN 329

Chinese Society: Class as Subculture. *By* MORTON H. FRIED 331

Applied Climatology. *By* ERWIN R. BIEL 336

Q
11
N524

SER. II, VOL. 14 *November, 1951* NO. 1

TRANSACTIONS
OF
THE NEW YORK ACADEMY OF SCIENCES

Editor
ROY WALDO MINER

Associate Editor
JAMES A. GOODE

Contents

Thrust Faulting—What Does It Mean? *By* CHESTER R. LONGWELL 2
The Role of Information Theory in the Inactivation of Maxwell's Demon. *By* HOMER JACOBSON 6
Polarized Light Navigation by Arthropods. *By* TALBOT H. WATERMAN 11
Viruses and Cells—A Study in Tissue Culture Applications. *By* GEORGE O. GEY AND F. B. BANG 15
Some Current Views on the Origin of Pernicious Anemia and the Absorption of Vitamin B_{12}. *By* C. C. UNGLEY 25
P-technique, A New Method for Analyzing the Structure of Personal Motivation. *By* RAYMOND B. CATTELL 29
Elementary L_1-Spaces. *By* L. A. MACCOLL 35
Cloud Seeding by Means of Dry Ice, Silver Iodide, and Sodium Chloride. *By* IRVING LANGMUIR 40
An Evaluation of the Technique of Cloud Seeding to Date. FERGUSON HALL 45
The Isolation from Soil of Fungi Which Cause Disease in Man. *By* CHESTER W. EMMONS 51

Copyright, 1951, by The New York Academy of Sciences

TRANSACTIONS of The New York Academy of Sciences, Series II, Volume 14, No. 1, November, 1951.
Entered as second-class matter December 12, 1947, at the post office at Baltimore, Maryland, under the act of August 24, 1912. This publication is distributed to members and is published monthly from November to June, inclusive, by The New York Academy of Sciences, Mt. Royal and Guilford Aves., Baltimore 2, Md. Editorial office: 2 East Sixty-third Street, New York 21, N.Y.

Executive Director: EUNICE THOMAS MINER

UNIVERSITY OF MICHIGAN

SECTION OF GEOLOGY AND MINERALOGY

THRUST FAULTING—WHAT DOES IT MEAN?*

By CHESTER R. LONGWELL†

The great thrust sheets of orogenic belts represent a distinctive type of crustal deformation. They are discrete masses that have been displaced, more or less intact, through distances which in many cases can be approximately determined. Relations of these sheets in any belt to each other, and to the general structural pattern, have been a subject of particular interest among students of tectonics, who hope to find in these relations some clues for solving the major riddle of orogeny.

Major thrust sheets, in so far as they are known through direct observation, seem to represent deformation at comparatively shallow depths, that is, within several thousands of feet or, at most, a few kilometers of the earth's surface. A large percentage of them involve only sedimentary formations of geosynclinal columns. Thus the Lewis thrust plate of northern Montana and southern Alberta consists of late Precambrian strata 12,000 feet or more in total thickness, on which, at the time of movement, may have rested younger Precambrian units, as well as Paleozoic and Mesozoic formations some additional thousands of feet thick. In southern Nevada and in the Appalachian belt, major displacements have occurred, essentially along bedding surfaces, in the lower parts of geosynclinal sections that originally totalled more than 30,000 feet, though it is not known how much thinning by erosion may have occurred before the plates were moved.

Thrusts exposed in the Appalachian Valley and Ridge province generally disappear downdip to the east. Along the eastern margin of the province, thrust sheets made of crystalline rocks, in part Precambrian, override the Paleozoic formations. According to a common interpretation, this is the "root region" where major thrusts spring from a deep zone of complex deformation, the *tectogene* of a popular theory. From this zone of intense compression, rock masses supposedly were forced upward and outward. Thrust blocks of massive basement rocks were driven against and over the Paleozoic formations in the Valley and Ridge province and these formations yielded by folding and by displacement along bedding thrusts. Those who accept this concept attribute the development of the tectogene to convection currents, or to some other mechanism of global scale that is capable of concentrating deforming stresses within a narrow mountain zone thousands of miles long.

Diagnosis of specific thrust masses raises serious doubts that all such units can be explained wholly as the result of outward thrust from an orogenic axis. Lawson (1922) has focused attention on mechanical difficulties in displacement of an ordinary thrust plate through several miles simply by plunger action. Bucher (1934, 1936) interprets the remnants of the Heart Mountain thrust in Wyoming as examples of far-travelled masses that probably owe their present locations to a special mechanism. The westernmost remnants of the plate, made up of Paleozoic carbonate rocks, protrude from a cover of volcanic rocks and lie on Cretaceous strata. Far to the east, other remnants lie on Eocene beds. On the assumption that these remnants once were parts of an intact sheet, the width and the minimum displacement of the plate must have been approximately 50 kilometers. Bucher points out that the thickness of the plate, as determined by the known stratigraphic column of the region, could have been no more than a few thousand feet, and that many of the formations are weak. This and other considerations prompted his suggestion that intense volcanic activity, perhaps accompanied by large updoming in the vicinity of Yellowstone Park, may have played a dominant part in displacement of the thrust masses. He cites the spectacular structure around the Ries Basin, in Germany, and also the thrusts around the Bearpaw Mountains, Montana, as perhaps comparable to the Heart Mountain situation, though on a smaller scale.

Haarmann's theory (1930) of sliding on the flanks of major uplifts is being revived, particularly by a group of European students, to explain the displacement of detached masses such as those of the Prealps, which lie tens of kilometers from any logical "zone of roots". Schardt, about 60 years ago, first recognized that the Prealps, with an overall length about 100 kilometers, are made up of

* This paper, illustrated with standard and Kodachrome slides, was presented at the meeting of the Section on October 1, 1951.
† Department of Geology, Yale University, New Haven, Conn.

several isolated thrust slices that lie one above another. Later Alpine students related these slices, which lie directly south of the Swiss Plain, to the East Alpine or Austride series of nappes which "root" in southern Switzerland. This relationship suggests colossal horizontal movement. Several investigators have suggested that an appreciable part of the displacement occurred by gravitational sliding on the north flank of the Aar—Mont Blanc uplift. A similar suggestion is made to explain detached thrust masses on the south side of the Alps, in northern Italy. The Dutch geologist de Sitter, who has studied and mapped intensively in the Bergamasc Alps, now concludes (1950) that a number of large klippen, distributed through an east-west belt 70 kilometers long, can be explained only as a result of gravitational sliding (*d'écoulement par gravit*). These masses, several of which have an imbricate relation similar to that of the Prealps, clearly were moved southward down the southern flank of the high Alpine chain. There is no recognizable "root" of a nappe further north, however, to which the remnants can logically be related. The klippen are composed chiefly of Triassic carbonate beds. Sliding occurred primarily on Permian shale, although imbrication has brought some blocks to rest at various Jurassic horizons. Upslope, a wide belt is underlain by older rocks, chiefly crystalline schists; this of course is the normal expectation, since a sliding plate would leave a widening gap in its wake, and any remnants of related rock units in the higher part of the chain would soon be removed by erosion.

De Sitter and some other European geologists consider gravitational sliding an incidental and minor process in orogenic belts which, in their view, owe their major structural development to deep-seated tectonic forces. Haarmann's concept, however, does not lack vigorous proponents. R. W. van Bemmelen (1949), after a long experience of field study and mapping in Indonesia, maintains that "primary tectogenesis" consists in development of elongate uplifts, or "undations," and that all folding and thrusting is a secondary result, from gravitational sliding. J. L. Rich advocates a similar mechanism (1951), in which a "magma blister" is the essential element for creating unstable slopes. In Rich's view a very low angle of slope above the marginal part of a "blister," perhaps one degree or less, may be sufficient for sliding and compressive deformation, since frictional resistance at the base of the "magma roof" will be very small. In this proposed scheme, the essential sliding unit, consisting of massive crustal rock, presses against and overrides geosynclinal formations, with resulting deformation by folding and thrust faulting. To provide potential for this vast work, it is required that the top of the "magma blister" be at shallow depth, *i.e.*, less than five kilometers, according to Rich's diagram (1951, FIGURES 1, 2). Study of the proposal brings strong doubts: What known principles dictate the assumed form of the blister, *i.e.*, a thin cake confined to the outer and presumably sialic shell, but with immense horizontal dimensions? Do the known physical properties of rocks justify assumption that thermal expansion of such a cake, only a few kilometers thick, would result in uplift sufficient for the required potential? How could the known horizontal movement of thrust plates within a typical geosynclinal belt, totalling many tens of kilometers, be accomplished without complete collapse of the "blister roof"? If the "blister" is confined to the sialic shell, as shown, whence came the basaltic lavas and the ultramafic intrusive bodies that have characterized early stages of growth and deformation in some geosynclines? In short, the basic assumptions of the hypothesis are open to serious question.

The best test of a proposed mechanism of orogeny comes from its application to known field relationships. Directly west of the Colorado Plateau, in the Basin and Range province, thick sedimentary formations of the Cordilleran geosyncline are broken and shingled by many large thrusts, of Cretaceous date. In a belt more than 175 kilometers wide, we look in vain for any basement rocks involved in the thrusting; all available evidence indicates that the deformation is confined to the geosynclinal section. In the vicinity of Death Valley some large masses of older Precambrian rocks are exposed, but there is no indication that they are broken by the Cretaceous thrusts. Where, then, is the plunger demanded by Rich's mechanism for deforming the sedimentary section? Even if evidence of a "blister roof" were present near Death Valley, could we accept the suggestion that stresses supplied by sliding of the roof were transmitted more than 175 kilometers in order to displace large thrust plates?

If the thrust sheets of southern Nevada record gravitational sliding, the required inclination must have affected these sheets directly. It is hardly conceivable that such a slope extended continuously across the entire belt, but we may assume

that the crest of an "undation" moved slowly from west to east, to cause a succession of great slides. FIGURE 1 represents a typical thrust involving a section of Paleozoic and Mesozoic formations five kilometers thick. A thrust of this type began as an anticlinal buckle, which was sheared across as the plate moved forward along weak Cambrian shale near the base of the section. On emergence at the surface, the thrust sheet, made up largely of carbonate beds, moved on Jurassic sandstone. To effect the displacement indicated required a force sufficient to rupture the thick section and move the plate about 25 kilometers, against the resistance of sliding friction. There is no reason to suppose that this resistance was small, particularly on the sandstone, which, from laboratory tests, is assigned a coefficient of friction of about 0.6.

An average inclination of 6½° elevates a plane surface about five kilometers in a horizontal distance of 50 kilometers. On such a slope the tangential component of gravity would cause sliding with a coefficient of friction less than 0.114, provided there is no other resistance. To produce a thrust of the kind shown in FIGURE 1, however, the section must first be ruptured, and the plate must be forced up a ramp to a higher level. The effective slope for sliding, therefore (A–B, FIGURE 1), would be no more than 1½°, on which sliding could occur only with a coefficient of friction less than 0.026. Even if the upper end of the 50-kilometer section stood 10 kilometers above the lower (11½° inclination), the effective slope A–B would be only 5½°, which would not permit movement with a coefficient as high as 0.1, even if we neglect the work of rupturing the section.

Ordinary engineering tests, therefore, do not seem to favor gravitational sliding as the primary mechanism in major thrusting movements. A more general argument on the same side of the question lies in the striking linear pattern, on a truly global scale, that characterizes the great mountain chains of the present era. It would seem that "blisters" or "undations" necessary to set the scene for sliding would result in a much more haphazard pattern. At any rate, I am not acquainted with a version of the sliding concept that meets the facts of mountain distribution in an impressive way.

The cause of orogeny is still an utter mystery, and we must dismiss no suggestion that offers any promise of eventual solution. A good case

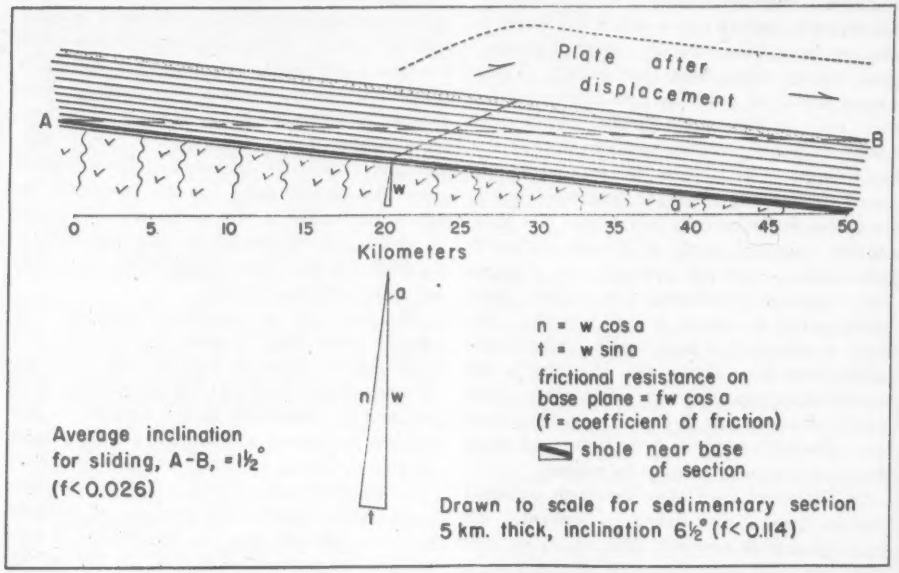

FIGURE 1. Possible application of the sliding mechanism to a typical bedding thrust.

has been made for gravitational sliding of superficial masses, "rootless" and of moderate size, on the steep flanks of the Alps. The same mechanism may well be an important auxiliary in development of major thrust sheets. Igneous agencies, as emphasized by Rich and others, are surely an important quantity in the equation of orogeny. I confess, however, to a conviction that a primary cause, deep-seated and thus far elusive, is reflected in the global pattern of the great mountain belts.

Bibliography

BUCHER, W. H. 1934. Problem of the Heart Mountain thrust. Geol. Soc. Am. **1933:** 57.

BUCHER, W. H. 1936. Remarkable folding, possibly due to gravity, bearing on the Heart Mountain thrust problem. Geol. Soc. Am. **1935:** 69.

DE SITTER, L. U. 1950. La tectonique d'écoulement dans les Alpes Bergamasques. Geologie en Mijnbonev, Dec. **1950:** 361–365.

HAARMANN, E. 1930. Die Oszillationstheorie. Ferdinand Enke, Stuttgart.

LAWSON, A. C. 1922. Isostatic compensation considered as a cause of thrusting. Bull. Geol. Soc. Am. **33:** 337–351.

RICH, J. L. 1951. Origin of compressional mountains and associated phenomena. Bull. Geol. Soc. Am. **62:** 1179–1222.

VAN BEMMELEN, R. W. 1949. Geology of Indonesia. Netherlands Government Printing Office, The Hague.

THE ROLE OF INFORMATION THEORY IN THE INACTIVATION OF MAXWELL'S DEMON*

By HOMER JACOBSON†

The early days of development of thermodynamics were marked by the development of the idea of irreversibility of natural processes. The Second Law directly implied the "heat-death," a state of the universe in which all possible degradations of energy into heat had taken place, the universe being at a constant temperature, and its entropy a complete maximum. Maxwell's demon was born somewhat whimsically[1], but also in possibility of fulfilling the wish that such a fate might not befall mankind. Natural philosophers since have clung to his conceptual reality perhaps more out of loyalty to the race than in the conviction that a workable model might be possible. It has been suggested frequently that bacteria or living tissues might function as such demons, in view of their wellknown selective powers.[2]

To treat Maxwell demons quantitatively, it is necessary to use entropy, the measure of their operations. Originally defined as the quotient of reversible heat and temperature, statistical approaches to thermodynamics showed entropy to be a quantity proportional to the logarithm of the number of possible states.[3, 4] In the Boltzmann H-theorem, $H = k \sum_{i=1}^{W} p_i \log_e p_i$, where H is a quantity showing the properties of entropy, p_i the probability of the ith state, and k the well-known Boltzmann constant. With present concepts of quantum statistics, this is generally expressed in the simpler form $H = k \log_e W$, where W is the total number of accessible states, each equally probable.

Maxwell's demon, then, was a being which decreased entropy by causing less probable states to ensue from his operations. Physically, he is generally imagined as guardian of a door through which some sorting process may take place. His two best-known roles are as "pressure demon," in which he effects a pressure change by allowing one-way passage of, say, gas molecules through his door, and as "temperature demon," in which he effects an entropy change by allowing only the hot molecules to pass through. In both cases, he is presumed to operate without expenditure of useful energy, or in any other entropy-increasing fashion. A third role we might call the "sorting demon," in which he separates molecules of different kinds, as does a uranium isotope separation plant, only without expenditure of energy. It will not be considered here.

We can use the demon in these two roles in appropriate cyclic processes. The "pressure demon" causes molecules to pass from a low to a high pressure chamber, in a continuous fashion. Simultaneously, a turbine is operated by allowing the same number of molecules to shoot through it from the high to the low pressure chamber. The source of the work is not in the demon, but in the heat acquired from the surroundings in the expansion process. Such a cyclic process gets work from heat, in defiance of the qualitative expression of the Second Law. Quantitatively, the demon produces an entropy decrease of $k \log_e r$, where r is the pressure ratio, for each properly transferred molecule. The "temperature demon" can be considered in a similar fashion, except that the chambers are insulated thermally from one another, and they have a temperature differential maintained by transfer of only the fastest, *i.e.*, hottest, molecules from the cold chamber into the hot one. Here work can be obtained by alternate expansion and contraction of a sample of gas thermally subjected to both chambers in turn.

This concept of a *demon ex machina* served to reassure humanity, until precise inquiries as to the metabolism of the demon were made. Szilard[5], in 1929, maintained that the operation of such a demon was attended with a more-than-compensatory entropy increase somewhere. Although his models were not altogether realistic, even for hypothetical experiments, his thesis was better than plausible, particularly for the case where the entire gas consisted of one molecule. Szilard[5] called the operation of the demon a "measurement", and maintained that $k \log_e 2$ units of entropy increase must take place every time the demon makes a measurement of choosing one of two alternatives.

* This paper, illustrated with lantern slides, was presented at the meeting of the Section on October 2, 1951.

† Department of Chemistry, Brooklyn College, New York, N. Y.

The major advance in our ability to treat this problem in a quantitative manner came with the Shannon-Wiener concepts[6, 7] of information. In defining information (info) with the equation, $I \equiv \sum_{i=1}^{W} p_i \log_2 p_i$, where p_i is the probability of the ith state, or with $I \equiv \log_2 W$, where W is the total number of equi-probable states, as above, Shannon recognized the effective identity of his concept with entropy, and, in fact, rather unfortunately used that name for it. Some terminological discussion resulted[8–10] which merely served to establish their essential equivalence. This, of course, is the result of their very definitions, if we count states of a physical system and those of an informational one to be correspondent. The only difference is in the factor $-k \log_e 2$. Information is expressed in the units of "bits" or binary digits, and entropy in e.u., or entropy units. Their conversion factor is the one mentioned, or that $\frac{1}{\log_e 2} = 1.443$ bits of info are equivalent to k e.u., each acting in an opposite sense. Any process in which entropy is compared to info should give this number in ideal situations.

Wiener[7] and Brillouin[11] were quick to realize that the demon, in acquiring information about the system on which it operates, must thereby effect an entropy increase as well as a decrease, and the net entropy change must be always equal to or greater than zero. Proof of this theorem was first suggested by Szilard,[5] whose word "measurement" was about the same as "information" in the Shannon[6] sense. Brillouin[12] has outlined a further proof of this theorem, with some excellent, but not entirely general, arguments. It must be shown (1) that a certain amount of info is necessary to effect a given entropy decrease, this being, of course, at least 1.443 bits/k e.u.; and (2) that a certain amount of entropy increase is necessary to effect the acquiring or use of the info, at least the inverse of the factor mentioned. This involves a net gain, or at best no change, in the entropy of the universe.

Part 1 of the theorem is susceptible to proof in several rather general cases. It was done for the one-molecule case by Szilard.[5] His calculations on the entropy of fluctuations,[13] as well as those of von Neumann,[14] can be made to give a result in harmony with the figure cited, when compared with Shannon's formula[6] for the entropy of a continuous distribution. The proof was attempted by Brillouin[12], using Maxwell's original model of two opposing temperature demons, one selecting cold and the other hot molecules, but this was not satisfactory, as we shall see later. We have shown how the pressure and temperature demons function under general assumptions, and calculated the informational *quid pro quo* in detail.*

The operation of these demon types (Case I and II, respectively) are schematically shown in FIGURE 1. The random vertical lines represent the energies and times of arrival of the molecules at the door. The demon must answer a question, for a series of short time intervals, t, something like, "Are one or more molecules which I must pass going to reach my door during this interval?" If the answer is "yes", he opens the door. The info required to answer such a question, according to Shannon,[6] is $-f \log_2 f - (1 - f) \log_2 (1 - f)$

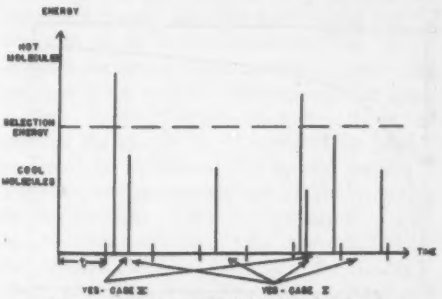

FIGURE 1. *Modus operandi* of the Maxwell demons.

bits, where f is the likelihood of the answer being "yes." For a situation in which an average of u particles reaches the doorway during the interval t, the answer is "yes" a fraction $1 - e^{-u}$ of the time. The amount of information required per opening of the door is $ue^{-u}/(1 - e^{-u}) - \log_2 (1 - e^{-u})$ bits, since an average of $u/(1 - e^{-u})$ particles per opening go through in the forward direction. And since an average of ru particles per opening go in the backward direction, the entropy change per opening is $-k \log_e r[u/(1 - e/^u) - ru]$. If we let the demon vary values of r and u at will, he can maximize the quotient $\Delta S/I$, where ΔS is the entropy change. FIGURE 2 shows the results of this maximization. The extent to which this quotient approaches $-k/1.443$ is a measure of the *quid pro quo* delivered by the

* Only an outline of the results of these calculations is presented here. While the details would be of great importance to Maxwell demons, they are of minor scientific significance. They will be furnished by the author on request, or may be published elsewhere.

demon, and can be called the "efficiency" of the demon process. The dotted line corresponds to maximizing with respect to r at fixed u, and the solid one to miximizing with respect to u at fixed r. In no case does the efficiency exceed one, but it approaches unity at high pressure ratios, the demon delivering more entropy decrease per unit of info furnished it.

Calculations for the temperature demon are much more involved. If the demon must select only that fraction p of the hottest molecules approaching his doorway, he will open the door for a fraction $1 - e^{-up}$ of the time intervals t, and pass an average of $up/(1 - e^{-up})$ molecules each time in the forward direction, (u being the average number of molecules, hot and cold, striking the doorway in time t, as before). To calculate the entropy decrease effected, it is necessary to calculate the

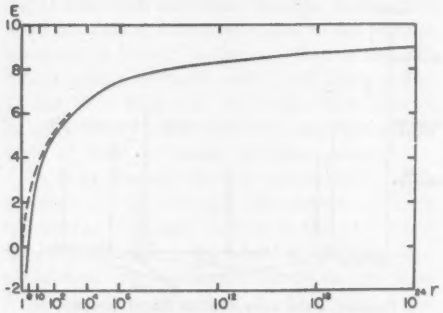

FIGURE 2. Efficiency of the pressure demon

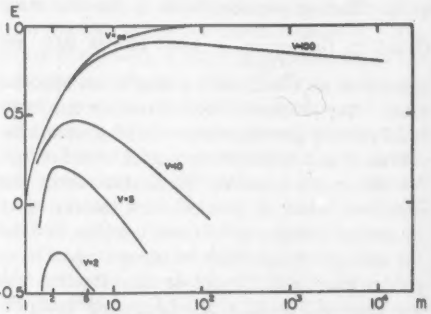

FIGURE 3. Efficiency of the temperature demon.

average temperature, T, of the selected molecules, and apply the Sackur-Tetrode equation[15] to the process of taking molecules from a cold compartment, temperature T_1, and putting them into a hot one, temperature T_2. The entropy change per door opening, for small values of up, is: $-\Delta S/k = (5/2)\log_e m - [(m-1)/m](T/T_1) + [(5/2)(\log_e m)(1 - m^{-1}) + 3(1 - 1/m)(m^{\frac{1}{2}} - 1)]$ u, where $m \equiv T_2/T_1$, and the gas is assumed to be monatomic and at the same pressure on both sides of the partition. The information per door opening required is the same as with the pressure demon, with u replaced by up. Making a few simplifying assumptions, and maximizing the efficiency with respect to u, optimal efficiencies can be approximately calculated.

The results are shown in FIGURE 3, the efficiency being plotted as a function of m, the temperature ratio, for varying sizes of v, which is the selection energy of the demon (FIGURE 1), divided by kT_1. It is seen that a good efficiency of the demon can only be obtained by taking a rather large v, *i.e.*, selecting only very fast, hot molecules, for passage. Furthermore, the number m must be large, as the maximum efficiency is $1 - 1/m$ for very large v. It is clear from this calculation why Brillouin's consideration of a demon operating with a small temperature differential[12] was an inapt example of the possibilities of the temperature demon. Under these conditions, the efficiency *must* be low.

These calculations establish more firmly the relationship between information and entropy, using a demon as a coding device. However, part 2 of the proof of the theorem above must be made. It will not be rigorously made here, but some additional arguments and considerations will be furnished. Brillouin[12] centered his suggested proof on the way in which the demon acquires the information, *i.e.*, his "sight". For the case in which he uses radiant energy, he shows that at least k e.u. are probably produced for each 1.443 bits of info obtained. Of course, the demon might obtain info in some other way, in which case additional proofs would have to be made.

Most generally, we can consider the demon as analogue of a being with perceptors, a central nervous system, and effectors, using these to perform his function. Szilard[5] recognized that a central nervous system would not be necessary for a demon. The minute he is given some means of recording, even for an instant, the info he needs, there is produced in his brain an order pattern, at least equal, in logarithmic loss of possible states, to that corresponding to the decrease of entropy. To say that the demon can effect this

order pattern in his brain is to beg the question of the functionality of the demon process, for this means that he could effect the order pattern elsewhere, say on a door-opening device. If he is made wholly automatic, however, there is no need to consider this part of the process, as the observation can lead directly to reflex effector action.

Here we suggest a different approach, namely a consideration of the demon's effectors, and the "weightless door". Granting the possibility of such a door in our hypothetical experiments, it is still possible to show that some kind of energy must be used in operating it reliably. For such a door will show an average energy of oscillation of $kT/2$, and a root mean square fluctuation energy of about kT, for each degree of freedom with which it is allowed to influence the passage of particles. We can construct it with only one degree of freedom, and ask what the demon must do in order to open or shut it. Clearly, he must set up some sort of energy barrier (we neglect quantum mechanical effects in this discussion) large enough to keep it still while he wants it shut, and remove this barrier when he wants to open the door. A change of kT in energy or more is indicated, between the open and closed door state. Now, it may be argued, this energy is not necessarily expended, but need merely be moved in and out, to cause the door to open or shut. But this is too glib a disposition of the matter. For the motion of the barrier is necessarily associated with matter at temperature T, itself subject to thermal fluctuation. Another barrier would be necessary to hold the first one in place, *ad infinitum*. It seems likely that an actual expenditure of unrecovered energy, of about kT, might be necessary, to effect this door opening. The reliability of the effector action should be an exponential function of this energy. We suggest the approximate relation, $\epsilon = e^{-E_d/kT}$, where ϵ is the fraction of time that the fluctuation energy of the door exceeds E_d, the energy the demon expends in keeping it shut or open. ϵ is the *unreliability* of the demon, when using an energy of E_d. It is about 0.4, *i.e.*, the reliability about 60 per cent, when an E_d of kT is used. This means an entropy increase of k e.u. per door opening, and corresponds to less than one bit of info, when the demon opens the door half of the time.

When the pressure and temperature demons operate at high efficiency, much more than k e.u. of entropy decrease is obtainable in one door opening, by factors of about $\log_e r$, and $(5/2)\log_e m$, respectively. In these cases, however, the reliability necessary to prevent leakage of molecules from the high-pressure or high-temperature compartments from completely vitiating the entropy decrease obtained, is higher. ϵ must be smaller, by factors of about r and $m^{5/2}$, and E_d must be higher, being of the order $(\log_e r)kT$, and $(5/2)(\log_e m)kT$, corresponding exactly to the entropies mentioned above. In no case, therefore, is it possible to operate a demon's door, without, in all likelihood, having to supply more entropy than the amount of effectible decrease.

It is interesting to apply these considerations to some speculations that have been voiced as to the reproductive process being an example of a demon-like one, and corresponding to a possible net entropy decrease. Detailed consideration like the foregoing should serve to dispel this view. If we consider the process as one of ordering amino-acid residues in an ambient substrate solution along a given "template" chain, which operates on the basis of the specific forces suggested by Jehle,[16] we conclude as follows: The specific forces for individual residues must exceed kT, for attraction to the template. They can be identified with E_d, the work performed by the demon in making his selection. For a Z-fold chain, the reliability of the process must be Z times as good as for a single residue, and ϵ about Z times smaller. This gives $E_d \sim (\log_e Z)kT$, for each residue, and a total energy of $\sim (Z \log_e Z)kT$. Now at the time of removal from the template, this quantity of energy must be applied, and it is difficult to imagine how, in any but an irreversible manner, causing a gain of $k(Z \log_e Z)$ e.u. of entropy. Since the entropy loss in arranging the Z units in a specific order in the chain is no greater than $k \log_e (Z!)$, or roughly $k\,Z \log_e (Z/e)$ e.u., there is seen to be, if anything, a gain of entropy in the process.

The last example epitomizes the role of information theory in this, and similar discussions. Information is not mentioned at all! The result appears in analogy with processes in which information is present in a transitory way. Information theory furnishes nothing that was not there before, except some definition, elegant points of view, and impetus to treat new topics with heretofore inapplicable generality.

Acknowledgment is made to Dr. N. M. Blachman for many stimulating discussions, and critical assistance with preparation of this manuscript.

Bibliography

1. MAXWELL, J. C. 1872. The Theory of Heat. Appleton, New York. Cited in ref. 12.
2. v. HELMHOLTZ, H. L. F. 1903 Lectures on the Theory of Heat. J. A. Barth, Leipzig. Cited in G. N. Lewis and M. Randall. 1923. Thermodynamics. p. 121, McGraw Hill, New York.
3. BOLTZMANN, L. 1912. Lectures on Gas Theory. J. A. Barth, Leipzig. Cited in Lewis and Randall, *Loc. cit.*, p. 126.
4. GIBBS, J. W. 1902. Chemical Principles in Statistical Mechanics. Chas. Scribner's Sons, New York. 1928. Or Collected Works of J. W. Gibbs. **2:** (14). Longmans, Green, Co., New York.
5. SZILARD, L. 1929. On the decrease in entropy effected by the interference of an intelligent being. Zeit. fur Physik **53:** 840–856.
6. SHANNON, C. E. 1948. A mathematical theory of communication. Bell Syst. Tech. J. **27:** 379–423; 623–656.
7. WIENER, N. 1948. Cybernetics. p. 71. John Wiley and Sons, New York.
8. BRILLOUIN, L. 1949. Life, thermodynamics, and cybernetics. Am. Sci. **37:** 554–568.
9. RAYMOND, R. C. 1950. Communication, entropy, and life. Am. Sci. **38:** 273–278.
10. OSTOW, M. 1951. The entropy concept and psychic function. Am. Sci. **39:** 140–144.
11. BRILLOUIN, L. 1950. Thermodynamics and information theory. Am. Sci. **38:** 594–599.
12. BRILLOUIN, L. 1951. Maxwell's demon cannot operate. J. Appl. Phys. **22:** 334–337.
13. SZILARD, L. 1925. On the extension of phenomenological thermodynamics to fluctuation phenomena. Zeit. fur Physik **32:** 753–788.
14. VON NEUMANN, J. 1932. Mathematical Foundations of Quantum Mechanics. Verlag. J. Springer, Berlin.
15. MAYER, J. E. & M. C. MAYER. 1940. Statistical Mechanics. p. 113. John Wiley and Sons, New York.
16. JEHLE, H. 1950. Quantum-mechanical resonance between identical molecules. J. Chem. Phys. **18:** 1150–1164. Errata, *ibid*, 1681.

SECTION OF BIOLOGY

POLARIZED LIGHT NAVIGATION BY ARTHROPODS*†

By TALBOT H. WATERMAN‡

That celestial navigation of a sort is utilized by certain animals has been known for a long time.[13] Fixes cannot be taken by this means, but celestial bodies are used as a compass permitting the organism to steer a straight course in a specific direction. The technique employed involves reference to the sun or moon as a direction finder, but enables the animal to navigate in any azimuth relative to this referent.

The particular behavior pattern concerned has been termed the light compass reaction.[4] This consists in the animal's walking, flying, or creeping in such a direction that the image of the celestial body remains fixed in a given spot within the visual field. Should this image be displaced by getting off-course, appropriate locomotor reflexes change the direction of movement until the image is back in place.

By this means, the animal's course is kept at a constant angle to the bearing of the celestial body and a corresponding steady direction of movement is maintained. The whole procedure is analogous to a pilot's use of a magnetic compass in steering the predetermined course of a ship. Even more comparable is man's technique of employing a sun compass or an astral compass in solving various special navigational problems, for in these instruments direction of light from celestial bodies rather than that of the horizontal component of the earth's magnetic field, is used to determine azimuth.

So long as the light source acting as a direction indicator is far away and the journey relatively short, a straight-line course will result from the light compass reaction. Should the light be nearby, however, keeping its retinal image in a constant position will result in a collision course along a logarithmic spiral. This in fact, is the pattern often realized in the attraction of moths to a street light or the classic candle flame.

The most interesting recent work on the light compass reaction in animals has been von Frisch's research on the honey-bee.[6] This demonstrates beautifully how worker bees ordinarily find their way to and from the hive with the aid of the sun as a compass. Earlier studies by various workers had disclosed similar methods of celestial navigation in ants, beetles, caterpillars, bees, spiders, myriapods and crustaceans among arthropods, while polychaete worms and gastropod molluscs had been found to behave in this way, too.

Since the light compass reaction is mediated through the animals' vision, the underlying mechanism of this behavior will depend in the first instance on the structure and function of their eyes. In most of the arthropods concerned, these are the lateral, compound eyes. As their externally obvious facets suggest, these structures consist of a few to 30,000 component visual units, the ommatidia. Each has its own cornea, lens, screening pigment, and photosensitive elements. Each ommatidium thus contributes a fraction to the total retinal mosaic. Unlike the concave, reversed, and inverted image found in the more familiar camera eye of the squid or vertebrate, the image in the compound type is convex, erect and not reversed.

However interesting such differences may be, and however much remains to be learned of the physiology of the compound eye, the sensory basis of the light compass seems clear enough. It consists of maintaining a predetermined part of the visual field fixed in a definite area of the retina. In other words, the bearing of the sun or moon is held within the visual angle subtended by a particular one or group of ommatidia. This is not to say that the many contributory aspects of the total behavior are understood, but merely that the sensory basis of the reaction appears perfectly straightforward.

There is, however, another kind of celestial navigation practised at least by certain insects, for which even such fundamental phases of the activity are incompletely understood. This is the polarized light compass discovered by von Frisch in the honey-bee.[5] Although these animals ordinarily may navigate with the sun as a reference azimuth, they still can maintain their sense of direction without seeing the sun, provided a small area of blue sky is visible to them. In a series of

* The author's research in this field is being aided by a contract with the Office of Naval Research.

† This paper, illustrated with lantern slides, was presented at the meeting of the Section on October 8, 1951.

‡ Osborn Zoological Laboratory, Yale University, New Haven, Conn.

fascinating experiments with mirrors and polaroid sheets, von Frisch has been able to show that the property of the blue sky requisite for this compass is the pattern of polarization in its reflected light. A close correspondence was found between the bee's sense of direction and the polarization of a patch of blue sky visible to the animal in a given azimuth and elevation at a particular time.[7]

This discovery provided the explanation of some of Santschi's[14] puzzling observations on ants. He found that ants going to and from their nest at twilight required a view of the heavens above to keep their sense of direction. A view of the surrounding terrain and the sky near the horizon was not enough for such orientation. These facts, discovered by screening different areas in their field of view, convinced Santschi that the ants were using celestial navigation. He ventured a suggestion that stars, not visible to the human eye under the prevailing light conditions, were being used for direction finding. Obviously, von Frisch's demonstration of polarized light navigation in bees indicated a possible reinterpretation of Santschi's data on ants. Subsequently, experiments both in the field and in the laboratory have substantiated the original observations, but have shown that the ant behavior in question does indeed depend on polarized light.[15, 16] The polarized light compass reaction therefore may be considered a well established phenomenon and one which is not limited to a single particular organism, although it has so far only been demonstrated in hymenopteran insects.

Effective study and eventual understanding of polarized light navigation in arthropods depends on development of broad insight into the whole subject. In terms of analysis, however, the whole may be separated into three elements which are its component aspects. First is the pattern of polarization to be found in the sky; second is the physiological mechanism whereby the compound eye can detect this; finally, there is the means whereby the organism can convert direction of sky light polarization into azimuth. The present discussion will deal largely with the first two of these items, since their thorough apprehension is prerequisite to an understanding of the third point.

Polarization of the light reflected from the blue sky is due to the scattering of the sun's rays by the molecules of the earth's atmosphere.[2] The basic pattern is therefore related to the position of the sun. Its main features will result from the primary (Rayleigh) scattering of sunlight. On the celestial sphere, polarization is linear and partial It varies from zero in the regions of the sun and anti-sun to a maximum at the equator of this system of solar coordinates. In this latter region, the theoretical maximum linear polarization from the primary scattering is 95 per cent. At all points on the celestial sphere, the plane of polarization (electric vector) is at right angles to the direction of the sun.

In actual fact, this simple basic pattern is modified by other factors. Secondary and higher order scattering of rays occurs in the earth's atmosphere. As a consequence, neutral points where the polarization diminishes to zero are produced about 20° above and below the sun and the anti-sun. Furthermore, several factors reduce the degree of polarization from its theoretical maximum. Dust in the atmosphere and the earth's reflection of light do so; in addition, the highest value is reached only when the angle of incidence of the sun's rays is 90° to the observer's zenith, *i.e.*, around sunrise and sunset, and is proportionately less at other times of the solar day. As a result of these effects, the maximum percentage polarization may be not more than 60 per cent. Clouds, even when thin, markedly reduce the percentage polarization, while a thick overcast completely depolarizes the sky light.

Nonetheless, from a meteorological point of view it is apparent that the blue sky presents a pattern of polarization which could certainly form the physical optical basis for a sky compass.

From a physiological point of view, however, the ability of an eye to analyze sky polarization is not so obvious. The human eye, for example, is little adapted for such a function. True, Haidinger's brushes, which may be observed in polarized light as a vague crosslike image in the fixation point of the visual field, indicate the electric vector of the source by the orientation of the blue sectors in the cross.[12, 17] Although the phenomenon is seldom noticed, it has been possible, at least for the author's eye, to see this figure in the zenith at sunset and hence recognize the direction of light polarization in the sky by inspection. Because of its weakly developed nature, however, such a polarized light analyzer of itself would hardly be an effective aid to navigation.

In the compound eye, on the other hand, an analyzer of a more practical sort must be present, at least in the insects that use a polarized light compass. The nature of this analyzer and its relationship to the other functional properties of

such arthropod eyes is one of the key points in the whole problem. In order to design effective experiments to elucidate this matter, one can make three alternative hypotheses. The analyzer might be the whole cornea of the eye behaving, for example, like a tourmaline crystal or a sheet of polaroid; or each facet might be an independent polarization analyzer; or, finally, the individual retinular cells might carry out this function individually.

The last possibility is particularly interesting since each ommatidium of a compound eye has a radially arranged rosette of such cells comprising its photosensitive region. If these were all analyzers, systematically but differently oriented, an efficient device with the required properties for a polarized light compass would be present. Autrum and Stumpf[1] have indeed considered the problem in this way and have found evidence which they interpret as supporting the third alternative: namely, that each retinular cell is an independent analyzer.

Their data, which were obtained from the compound eyes of the honey-bee and the fly, *Calliphora*, consist of electroretinograms. These are the electrical responses which may be recorded from the surface of the cornea when an eye is illuminated. Autrum and Stumpf found the amplitude of this response, when the stimulating light was turned on, to be the same, regardless of the plane in which it was polarized. This was true for illumination of large areas of the eye or single facets. On this evidence, the cornea as a whole, or even a single facet, would not appear to be acting as polarization analyzers. It was found, however, that unpolarized light had to be 15–30 per cent more intense to produce as large an on-effect in the electroretinogram as did polarized light. This result could support the third hypothesis if effective light intensities were such that the retinal elements were operating in an appropriate range of the non-linear function relating on-effect amplitude to stimulating light intensity. Autrum and Stumpf conclude that the facts do support this alternative and that the single retinular cells therefore are the analyzers.

More direct evidence for or against this hypothesis could be obtained if nerve impulses in single optic nerve fibers were studied as a function of polarization of the stimulating light. The author has conducted such experiments on the lateral eye of *Limulus*, the horseshoe crab.[18] In single elements isolated in the classic Hartline manner,[8] the frequency of discharge was found to vary systematically with the plane of polarization, changing from maximum to minimum response as this plane moved through 90°.

An adequate interpretation of these results depends, however, on a more thorough knowledge of the functional organization of the *Limulus* retina than we now have. It has generally been assumed that the discharges recorded in single elements of this optic nerve are those originating in one retinular cell, a single sensory element of an eye. Histological studies being carried out by the author (as yet unpublished) make it imperative to test this assumption critically. The optic nerve is clearly made up of nerve fibers of three distinct size ranges. The ones of intermediate diameter, which seem to be the most likely source of the well-studied single element discharges, correspond in number with the ommatidia but not with the retinular cells, which are far more numerous. The need for a fuller understanding of the whole system is therefore demonstrated.

If the results obtained so far are indeed the responses of single retinular cells, they provide positive support for Autrum's hypothesis. On the other hand, if they are discharges from the eccentric cells of the *Limulus* ommatidia, or if they are synchronous discharges in several or all of the retinular fibers of single ommatidia, their interpretation is less obvious. Only further work can resolve this dilemma. It is pertinent to note that in answering the particular question of polarization analysis here raised, a number of basic issues in compound eye physiology will need to be settled by the way.

Although the underlying mechanism of polarized light analysis is thus incompletely known, it is possible to predict the kind of optical system which must be found somewhere in an eye with this ability. Such a system must possess two properties, whether in the cornea and lens, or the rhabdome and retinular cells. First is birefringence, the property shown by anisotropic bodies of transmitting light at two different velocities depending on its polarization. Second is a means of eliminating one of these rays before it emerges from the birefringent element. In compound eyes, the first of these requirements is met at least in the *Limulus* eye, where the corneal lens (no crystalline cone is present) shows a negative uniaxial birefringence with respect to its optical axis (unpublished observations by the author). Chitinous

arthropod integument in general is birefringent,[11] and the corneal structures of some crustaceans show a pattern of birefringence due to crystalline calcification.[3]

The second optical requirement could be met either by absorbing one ray or by reflecting it out of the effective pathway of the system. Absorption of one ray is what happens in dichroic media, such as tourmaline crystals or polaroid. Reflection of one ray is what happens in calcite cut as a Nicol prism. Interesting evidence that the latter process occurs in the ommatidia of a dipteran compound eye has been found by Menzer and Stockhammer.[9] The correlation of this kind of optical data with the sensory physiology and neurology of these eyes will yield most important results for the problem at hand.

Finally, it is noteworthy that polarized light navigation is useful to man.[10] In the high latitudes of polar regions twilight lasts for long periods; in the extreme case of the geographical poles at the time of the equinoxes, there is a period of eight days between the final disappearance of the sun and first appearance of the brightest stars. During more than a week then, no standard celestial navigation can be used. Since the magnetic compass is quite unreliable near the earth's magnetic poles, the human navigator in these high latitudes is badly uninformed on azimuth. Obviously, this deficiency could be remedied easily during clear weather if an effective means of using the polarization pattern of the sky were devised. Some beginnings in this direction have been made with the development of a type of sky compass, utilizing this principle.[10] Improvements in such an instrument for practical use appear to be desirable and not impossible. It is just conceivable that the lessons to be learned from the polarized light navigation of arthropods will permit the planning and design of instruments and methods that will aid man to solve the same navigation problem.[19, 20]

Bibliography

1. Autrum, H. & H. Stumpf. 1950. Das Bienenauge als Analysator für polarisiertes Licht. Zeit. für Naturforsch. **5b:** 116–122.
2. Chandrasekhar, S. & D. Elbert. 1951. Polarization of the sunlit sky. Nature **167:** 51–55.
3. Dudich, E. 1931. Systematische und biologische Untersuchungen über die Kalkeinlagerung des Crustaceenpanzers in polariziertem Licht. Zoologica **30:** Hft. 80, 1–154.
4. Fraenkel, G. S. & D. L. Gunn. 1940. The Orientation of Animals. pp. viii, 352. (Reference to pp. 100–119.) Oxford University Press, Oxford.
5. von Frisch, K. 1948. Gelöste und ungelöste Rätsel der Bienensprache. Naturwissenschaften **35:** 12–23, 38–43.
6. von Frisch, K. 1950. Bees: Their Vision, Chemical Senses, and Language. pp. xiii, 119. Cornell University Press, Ithaca.
7. von Frisch, K. 1951. Orientierungsvermögen und Sprache der Bienen. Naturwissenschaften **38:** 105–112.
8. Hartline, H. K. 1942. The Neural Mechanisms of Vision. Harvey Lectures, 1941–1942, pp. 39–68. Science Press, Lancaster, Pennsylvania.
9. Menzer, G. & K. Stockhammer. 1951. Zur Polarisationsoptik der Fazettenaugen von Insekten. Naturwissenschaften **38:** 190–191.
10. Moody, A. B. 1950. The Pfundt sky compass. Navigation **2:** 234–239.
11. Richards, A. G. 1951. The Integument of Arthropods. pp. xvi, 411. Reference to p. 130ff. University of Minnesota Press, Minneapolis.
12. Rösch, S. 1941. Über die Haidingerschen Buschel. Mitteil. Leitz-Werke **63:** 65–72.
13. Santschi, F. 1911. Observations et remarques critiques sur le mécanisme de l'orientation chez les fourmis. Rev. Suisse Zool. **19:** 303–338.
14. Santschi, F. 1923. L'orientation sidérale des fourmis et quelques considérations sur leurs différentes possibilities d'orientation. Mem. Soc. Vaudoise Sci. Nat. **1:** 137–176.
15. Schifferer, I. 1950. Cited (p. 220) by K. von Frisch: Die Sonne als Kompass im Leben der Bienen. Experientia **6:** 210–221.
16. Vowles, D. M. 1950. Sensitivity of ants to polarized light. Nature **165:** 282–283.
17. de Vries, H., R. Jielof, & A. Spoor. 1950. Properties of the human eye with respect to linearly and circularly polarized light. Nature **166:** 958–959.
18. Waterman, T. H. 1950. A light polarization analyzer in the compound eye of Limulus. Science **111:** 252–254.
19. Waterman, T. H. 1950. Flight instruments in insects. American Scientist **38:** 222–238.
20. Waterman, T. H. 1951. Zoology in navigation. Symposium on the Sciences in Navigation. Institute of Navigation. (In press)

VIRUSES AND CELLS—A STUDY IN TISSUE CULTURE APPLICATIONS*

I. Cells Involved—Availability and Susceptibility†

By G. O. GEY AND F. B. BANG‡

The use of cultured strains of cells would appear to provide adequate means of studying the susceptibility of specific lines of cells to homologous or heterologous viruses under conditions which permit some control of the environment, and more or less direct observations of cell and colony responses to the effects of a given virus or viruses. Simple continuous culture procedures have made it possible for us to maintain a wide spectrum of cell types as uniform strains for years in a variety of media substrates.[1] For successful virus cultivation in cells from strain cultures, it would appear to be important to use an homologous system of media, cells, and virus, yet experience has shown that this is not necessary and, in some instances, may not be desirable. Extensive summaries on the use of tissue cultures for viral propagation have appeared, but cover chiefly the results obtained with short period survival of primary explants or with serial virus transfer to new primary explants, as in the Maitland procedure.[1] The review of Robbins and Enders[2] emphasizes many points that those engaged in the problems of continuous tissue cultivation have also stressed as important for a better understanding of virus growth in cells. There appears to be considerable need for a wider extension of interest into virus-host cell and colony relationships, such as those obtained in continuous cultures of specific cell types. We hope that the evidence presented on the effects of growth of several viruses on continuous cultures will emphasize the opportunities that are provided by the use of various cell types maintained in continuous roller tube cultures for the study of cellular responses to virus growth.

The study of virus growth with specific cells in continuous cultures sometimes requires extended periods of observation and serial treatment of cultures over long periods. When these conditions prevail, media uncontaminated with viruses should be used. At the present time, we cannot turn to media made up of chemically definable components, *i.e.*, synthetic media, since they have thus far not been shown to be capable of maintaining cell growth. For the maintenance of continuous cultures, we still need such media components as plasma, serum, and tissue extract, alone or in various combinations. These constituents of homologous origin are commonly used to maintain chick cells and introduce the hazard of viral contamination, even when obtained from carefully selected flocks. Extensive studies on the growth of Newcastle virus in cultures require the use of media components obtained from hosts that are virus and antibody free.

The prevalence of lymphomatosis in flocks of birds in general provides another example of a source of contaminating virus whose effects on cells would have to be determined in any given prolonged experiment. The work of the East Lansing group[3, 4] has demonstrated the difficulties of developing lymphomatosis-free stock by isolation. It is quite unlikely, therefore, that flocks exist entirely free of this and even other viruses unless the "germ-free" stocks of Reyniers[5] should be proved to be entirely "virus-free."

The recent work of Beard and associates,[6] on the presence of a sedimentable component obtained from the plasma of birds with avian leucosis, further complicates the problem. Several years ago we observed an interruption in growth of a strain of chick macrophages with degeneration of all cells. This event was interpreted as the result of the destructive growth of a contaminating virus, possibly contributed by one of the homologous media components. Macrophages are known to support viral growth in varying circumstances.[7–10] The electron micrographs shown in FIGURES 1A and 1B illustrate that some degenerating cells occasionally found in stock or control cultures may show particles indistinguishable from virus. This finding further justifies our efforts to obtain virus-free media.

Viruses have been grown in an heterologous system of media and cells[11] indicating the non-specificity for cell types exhibited by the growth of some viruses. We observed the growth in and the destruction of rat cells by the virus of lymphopathia venerea and also the growth of encephalitis virus in a rat cell strain.[12, 13] Those interested in the wider use of cell strains may be inclined to use

* The research was supported in part by grants-in-aid from the National Cancer Institute, and the National Microbiological Institute, U.S.P.H.S.

† This paper, illustrated with lantern slides, was presented at the meeting of the Section on May 14, 1951.

‡ Departments of Surgery and Medicine, The Johns Hopkins Hospital and University, Baltimore, Md.

UNIVERSITY OF PITTSBURGH LIBRARIES

such readily available media components as ox serum, ox embryo extract, horse serum, human placental cord serum, or ascitic fluid. Their abundance and ability to support growth of many types of cells appears to justify their wide use for cell cultivation. When a composite substrate containing several heterologous components is used, the potential background of contaminating viruses may be greater than with homologous media. To date, however, little is known of the role of such contaminating viruses when media components are used for the growth of cells homologous to some components or in any combination of heterologous components. Horse serum, for example, when used as a component of the medium, introduces the hazard of swamp fever virus contamination. This virus has been known to persist in the blood of the same host for periods over twenty years.[14] When media components from human sources are used, one must take into consideration the role which the resistant hepatitis virus might play in any observed alteration of cell growth, especially in an homologous system. How fastidious these viruses are for specific cells and media components is unknown. It would seem desirable, therefore, to devise procedures for

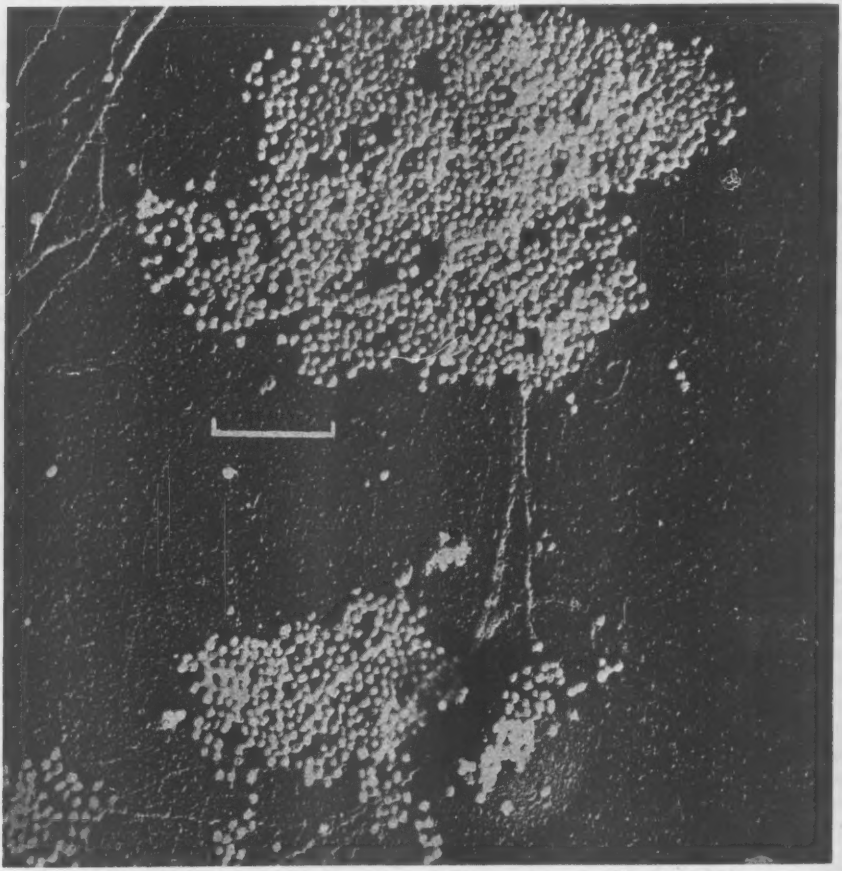

FIGURE 1A. Peripheral margin of chick embryo cell cultivated in media used for routine stock cultures and showing masses of particles indistinguishable from virus.

the removal of viruses from natural media components wherever there exists a possibility of natural or unnatural contamination.

We have probed several possible means of destroying viruses in natural media components such as plasma, serum, and tissue extract, but as yet have found no desirable method which retains completely the natural media components in unaltered form. The kind cooperation of Drs. Brasch and Huber of the Electronized Chemicals Corporation has made it possible for us to test sterilized media components, following bombardment with fast electrons from the Capacitron[15] at minus 78°C. We have also explored the value of ultraviolet irradiation in this field. The most successful results to date were those obtained from a batch of U.V. irradiated horse serum kindly prepared for us by Drs. Hampil and Spizizen of the Medical Research Division of the Sharp & Dohme Company. The results summarized in TABLE 1 show that a strain of rat malignant cells and their specific normal prototypes can be maintained indefinitely in Capacitron irradiated media when given a dose of approximately two and one-half million "rep."* This value is far above doses

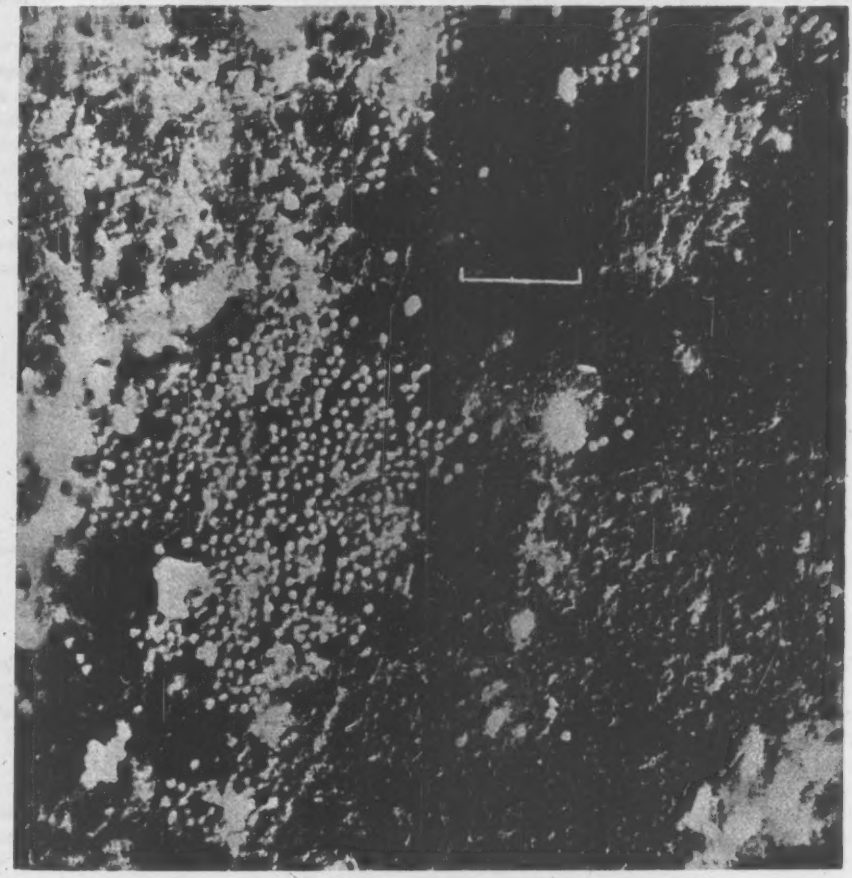

FIGURE 1B. Large portions of cytoplasm of same cell destroyed by this "viral" contaminant.

* Roentgen equivalent physical.

demonstrated to kill many viruses tested by Dr. Huber and associates. It is apparent from TABLE 1 that the malignant strain T333 can grow better in irradiated media than its normal prototype, strain 14p. This holds true for both types of radiation used. No experiments on the growth of viruses in cells maintained with such media have been carried out so far.

It would appear that simple filtration would rid some media components of viruses without altering greatly the composition of the components necessary for cell growth. This method, however, cannot be employed to remove viruses from a viscous tissue extract. We have at times considered the use of chemical agents, including nitrogen mustard, but can offer no culture data to justify their use in this connection. Media components which introduce viral antibody justify efforts to fractionate these components with the object of eliminating antibody. Media reconstructed from fractions and made up as a substrate for cultured cells definitely need further exploration. Apparently, the present methods of fractionation do not guarantee destruction of all viruses.

The distribution and fate of added viral antibody in a tissue culture preparation should also be given some consideration. We have demonstrated the survival of virus in cultured cells in the presence of specific antibody. Sera containing antibody to Newcastle virus were added to the medium of chick cultures infected with Newcastle and were observed to neutralize virus in the fluid medium. When the antibody was progressively removed by media renewals, however, active virus was again produced by the cultured cells which had harbored it during the two weeks of continuous exposure to antibody. One may postulate, however, that all the cells in a culture are not fully exposed to the renewable substrates. Cells bound up in a semi-solid substrate evidently cannot exchange high molecular components or particles readily through the surrounding gelated medium. We believe that this is one of the factors that influences the dissemination of virus in a cell culture, whether the barrier be the gelated substrate or the intercellular ground substances produced between the cells when only a fluid medium is used.

As noted above, much work has been done on the exposure of primary tissue explants to viruses. The system, however, does not permit us to evaluate specific host-cell virus relationships, since most primary explants contain a variety of cells. FIGURES 2 A, B, C, illustrate some of the cell types which proliferate from human embryonic liver following primary explantation and which persist for long periods thereafter. The most peripheral area of many of these cultures may show numerous young blood cells and liver fibroblasts. The central area and intermediate zone may show large masses of liver cells or long cords of epithelium. In other areas, dense cords of capillaries rich in embryonic blood appear. To simplify the study of the availability and susceptibility of cells to virus, one should use cultures of uniform cell strains which permit a more exact evaluation of cell and culture responses. We have chosen, therefore, to work for the most part with strain cultures.

Many stable strains of animal and human cells are available that can be grown easily for indefinite periods. A few apparently stable cultures appear to carry on for long periods with more than one cell type present, such as the symbiotic relationship of normal and malignant cells.[16] Stable strains of malignant cells provide abundant material for viral cultivation and in some instances

TABLE 1

GROWTH OF 14p AND T-333 IN ROLLER TUBES USING STERILIZED MEDIA (100-DAY TEST RUN)[1]

Media	*Control*		*Capacitron irradiated Dose* *Low*[2]		*High*[3]		*U-V irradiated*	
	14p	T-333	14p	T-333	14p	T-333	14p	T-333
B.E.E.[4]—10%, Cord serum—50%	very good (40d)[5]	very good (40d)[5]	good	good	fair	good		
B.E.E.—10%, Horse serum—50%	good	good	poor	good	poor (35d)[6]	good	poor (35d)[6]	good

[1] Media which can produce progressive growth with sub-cultures for 100 days demonstrate sufficient maintenance for continuous growth.
[2] Low—2,450,000 "rep".
[3] High—4,600,000 "rep".
[4] B.E.E.—Bovine Embryo Extract.
[5] Cultivation of controls stopped at 40 days.
[6] Series repeated to check approximate 35-day end-point.

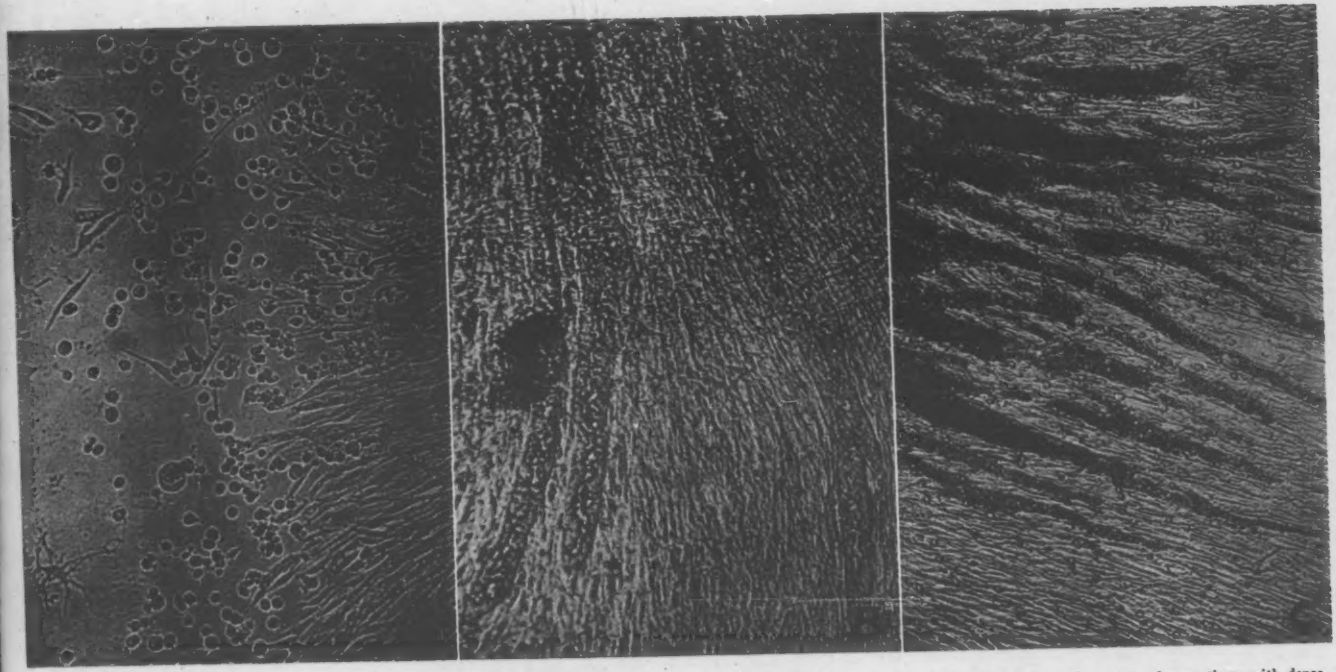

FIGURE 2A. Peripheral margin of culture of human embryo liver showing fibroblasts, young red cells, and macrophages.

FIGURE 2B. Intermediate zone of same tissue showing cords of liver cells in dense outgrowth of spindle cells.

FIGURE 2C. Intermediate zone of same tissue with dense long capillaries filled with young blood cells.

UNIVERSITY OF MICHIGAN LIBRARIES

provide an opportunity to compare the viral susceptibility of the malignant cells with their specific normal prototypes. We have had an opportunity recently to compare the susceptibility of a twelve-year-old strain of normal rat fibroblasts of strain 14p (FIGURE 3B) with a ten-year-old tumor cell derivative of this strain T-333 (FIGURE 3A) when such continuous cultures are exposed to the virus of Eastern Equine Encephalomyelitis (E.E.E.). These studies demonstrate a high degree of susceptibility of the malignant cell to this virus, with very low or no susceptibility of the normal prototype.

These and many other cell strains grown in roller tube cultures constitute good cell systems for the evaluation of the destructive effects of viruses on them. A simple fluid medium composed of 50 per cent human placental cord serum and 10 per cent bovine embryo extract will grow many lines of cells as a single cell layer on the glass wall of a roller tube. Under these conditions, the cells are apparently available to the action of a virus introduced into the fluid medium. The distribution of the cells of normal strain 14p is illustrated in FIGURE 4. Here, the cells exposed to undiluted virus differ very little in appearance from the control strain. The E.E.E. virus has no discernible effect on this normal cell strain and soon disappears from the cultures.

The tumor cell derivative T-333 grown under comparable conditions shows a ready response to the addition of virus with the destruction of its cells in a few days. FIGURES 5A and B illustrate the difference in appearance between a stock culture of this strain and one destroyed by virus. With such cells, although grown on glass in a fluid medium, complete destruction of the colonies is not always attained (FIGURE 6). We have attempted to evaluate this partial destruction and the factors which may play a part in it.

Under differing circumstances, a ring of destroyed cells may be seen surrounding a colony with a translucent central area of apparently intact cells, in cultures infected with destructive viruses.

FIGURE 3A. High power phase images of ten-year-old rat sarcoma strain T-333. Note large nucleus, ring of inclusion droplets,and thick character of cells.

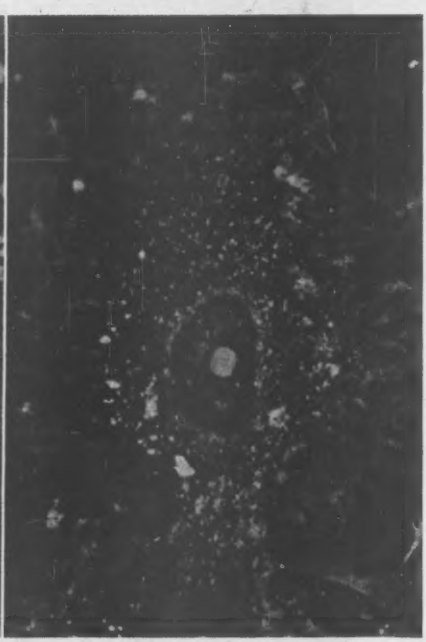

FIGURE 3B. High power phase image of thinly spread normal adult rat mesenchyme cell from twelve-year-old strain. This specific normal prototype to cells shown in FIGURE 3A spreads out more readily with more prominent fibrous structure, has fewer inclusion droplets, and smaller nuclei.

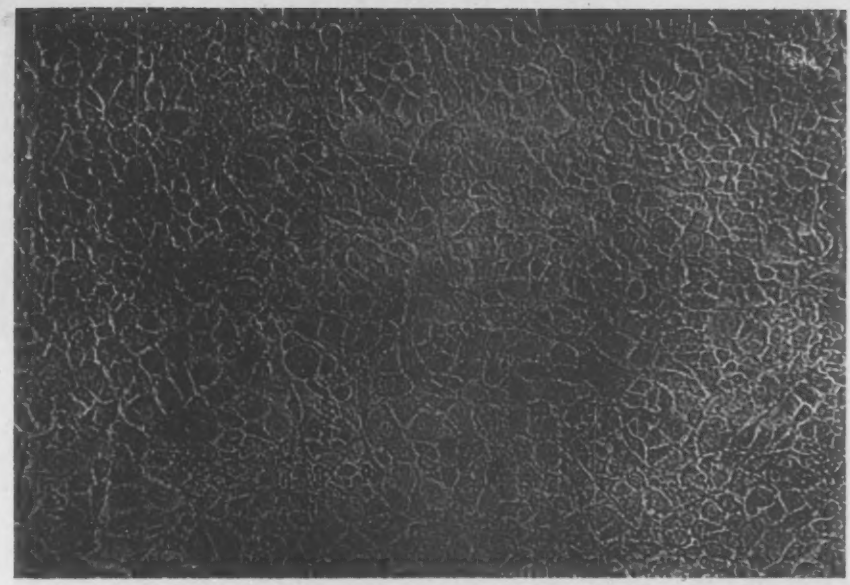

FIGURE 4. Twelve-year-old strain, 14p, of adult rat mesenchyme cells of subcutaneous areolar tissue origin. These grow in fluid media as a single-cell layer on glass. This culture treated with undiluted E.E.E. virus grown in the embryonated egg (C.A. fluid) is apparently unaffected by virus. Culture looks like the control.

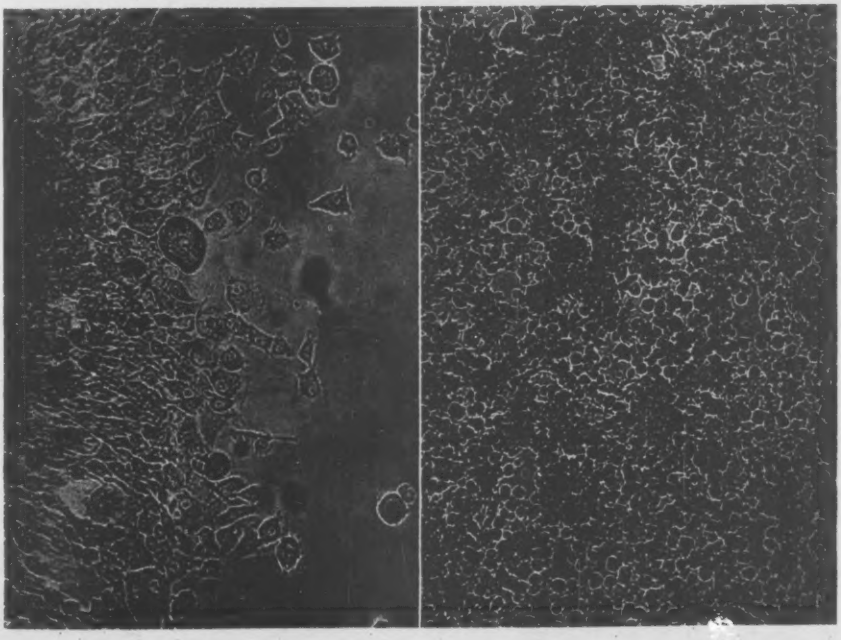

FIGURE 5A. Control culture of ten-year-old strain of rat sarcoma strain T-333 derived in tissue culture from normal strain 14p. Cells grown in fluid media on glass. Tumor cells larger than normal prototype with much greater variation in cell size.

FIGURE 5B. Culture of same strain, T-333, destroyed by E.E.E. virus. Dark cell casts remain.

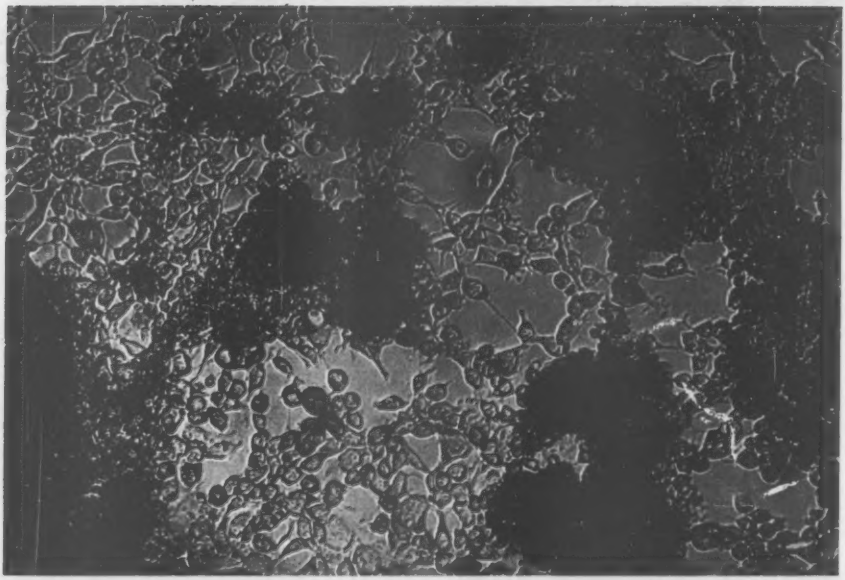

FIGURE 6. A culture of rat strain T-333 showing early heavy destruction of cells now forming masses of cell casts and debris and being replaced by new sarcoma cells emigrating from beneath black granular central area.

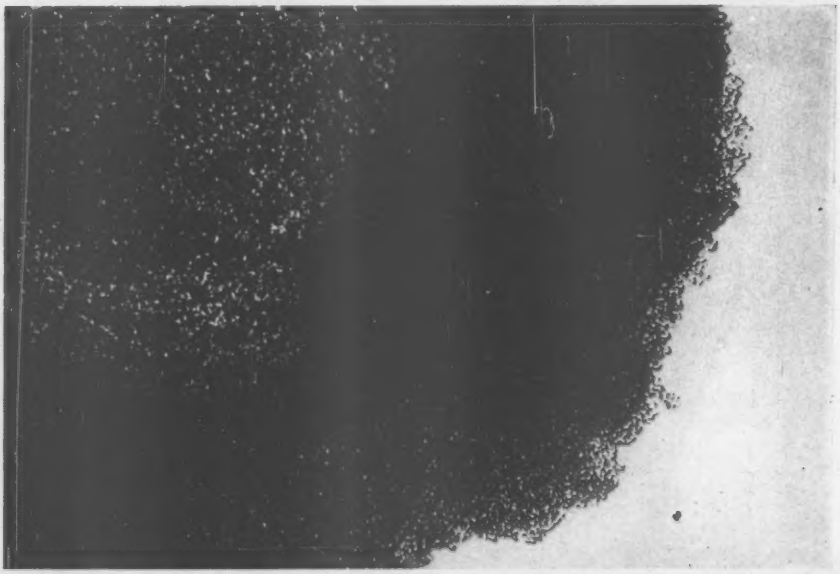

FIGURE 7. Residual colony of normal adult muscle fibroblast strain M-2 following exposure to E.E.E. virus. The destroyed cells form a dark necrotic ring over and around a paler central area containing active cells not yet destroyed by virus.

Such a progressive change in the colony appearance may be seen in a susceptible strain of rat muscle fibroblasts, strain M-2, FIGURE 7, previously infected with E.E.E. virus. A similar phenomenon has been observed in an homologous system of media, cells, and virus with a less intense ring of cell destruction in colonies of a strain of chick muscle fibroblasts previously infected with Newcastle virus. When these highly susceptible chick cells are grown in plasmatic media and exposed to this virus, most of the cells will be destroyed within about a week, but isolated strands and will be discussed in Part II. Here one must consider the infected, degenerating cells as potential single virus units. Since the roller tube does not provide static conditions, it may be important to mention here experiments which demonstrate the localization of virus in static slide cultures. These static cultures were composed of thin colonies of rat malignant cells, T-333, covered with a static supernatant fluid to which a few LD 50's of encephalitis had been added. Following a period of incubation, it was possible to demonstrate focal necrotic lesions. This would

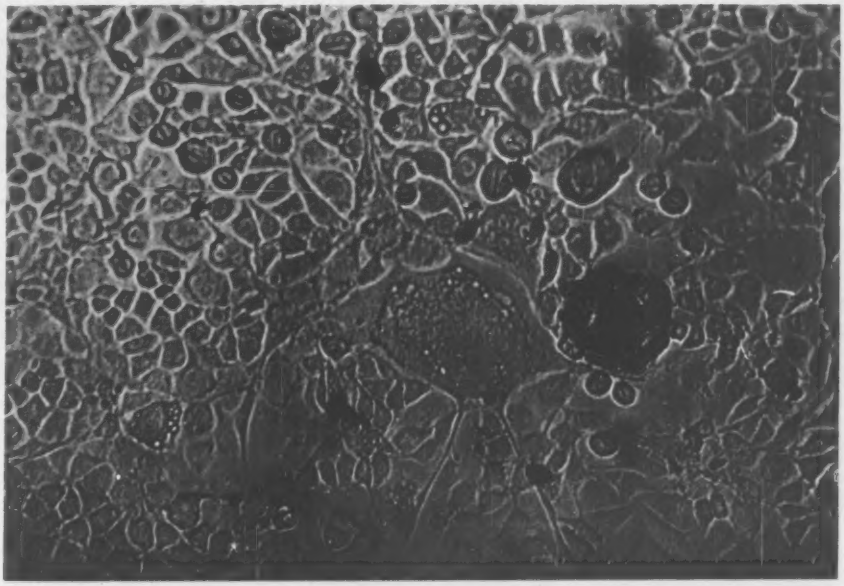

FIGURE 8. Twelve-year-old strain of rat sarcoma 72 of *in vitro* origin. E.E.E. virus grows in this strain for apparently indefinite periods with destruction of some cells. Note cell casts and large dead multi-nucleated cell adjacent to a healthy one. Many dividing cells present.

of cells buried in clot will succumb to virus only after the strands become accessible at one point or another, even weeks later. These results demonstrate the inability of virus particles in general to penetrate cell masses, either because of the presence of an intracellular matrix, or the gelated medium. A more precise evaluation of these events in terms of virus localization is needed.

FIGURE 8 shows small black cell casts and one large degenerated cell in a very active colony of rat sarcoma strain 72, known to produce E.E.E. virus during continuous cultivation. This represents an intermediate type of susceptibility to this virus appear to provide a means for titrating virus units in a culture fluid and also provides a possible method of studying the extension of virus in cell cultures.

From the observations reported here, we cannot escape the conclusion that a better understanding of the cell's susceptibility to virus requires an inquiry at the level of fixed cell systems as in continuous cultures.

Bibliography

1. MAITLAND, H. B., & M. C. MAITLAND. 1928. Cultivation of vaccinia virus. Lancet **2**: 596.
2. ROBBINS, F. C., & J. F. ENDERS. 1950. Tissue

culture techniques in the study of animal viruses. Am. J. Med. Sci. **220**: 316.

3. Waters, N. F., & C. O. Prickett. 1944. The development of families of chickens free of lymphomatosis. Poultry Sci. **23**: 321–333.
4. Burmester, B. R., & E. M. Denington. 1947. Studies on the transmission of avian visceral lymphomatosis. Cancer Research **7**: 779–785.
5. Reyniers, J. A., P. C. Trexler, R. F. Ervin, M. Wagner, H. A. Gordon, & T. D. Luckey. 1950. Germ-free chicken nutrition. I. Gross development and vitamin utilization studies employing white Leghorn chicks. J. Nutrition **41**: 31–49.
6. Beard, Dorothy, E. A. Eckert, T. Z. Csaky, D. G. Sharp, & J. W. Beard. 1950. Particulate component of plasma from fowls with avian erythro-myeloblastic leucosis. Proc. Soc. Exp. Biol. & Med. **75**: 533–536.
7. Carrel, A. 1926. Some conditions of the reproduction in vitro of the Rous virus. J. Exper. Med. **5**: 647–668.
8. Carrel, A., & A. H. Ebeling. 1922. The transformation of monocytes into fibroblasts through the action of Rous virus. J. Exper. Med. **36**: 365.
9. Benjamin, B., & T. M. Rivers. 1931. Regeneration of virus myxomatosum (Sanarelli) in presence of cells of exudates surviving in vitro. Proc. Soc. Exper. Biol. & Med. **28**: 791–792.
10. Bang, F. B., E. Levy, & G. O. Gey. 1951. Some observations on host-cell virus relationships in fowl pox. I. Growth in tissue culture. II. The inclusion produced by the virus on the chick chorio-allantoic membrane. J. Immunol. **66**: 329.
11. Feller, A. E., J. F. Enders, & T. H. Weller. 1940. The prolonged coexistence of vaccinia virus in high titre and living cells in roller tube cultures of chick embryonic tissues. J. Exp. Med. **72**: 367.
12. Gey, G. O., & F. B. Bang. Unpublished data.
13. Gey, G. O., & F. B. Bang. 1950. A study of the effect of the virus of eastern equine encephalomyelitis on normal and tumor cells in tissue culture and by electron microscopy. Cancer Research **10**: 219.
14. Balezet, S. 1943. Anemie infectiense des equides, quoted from C. Levaditi, P. Lepine, et J. Verge. Les ultravirus des maladies animales. Paris.
15. Brasch, A., W. Huber, U. Friedemann, & F. B. Traub. 1949. Action of high intensity electrons on biological objects. Proc. Rudolf Virebow. Med. Soc. in New York **7**: 3–24.
16. de Bruyn, W. M. *In vitro* cultivation of malignant lymphoblasts of transplantable mouse lymphosarcoma M B (T86137) without typical mesenchyme cells. Bijdragen tot de Dierkunde, Jubileum nummer, 1949.

SOME CURRENT VIEWS ON THE ORIGIN OF PERNICIOUS ANEMIA AND THE ABSORPTION OF VITAMIN B_{12}*

By C. C. UNGLEY†

The Gastric Lesion in Pernicious Anemia

The essential underlying cause of Addisonian pernicious anemia and of its neurological manifestations is atrophy of the body mucosal region of the stomach. The significance of the gastric defect so clearly demonstrated by Castle's experiments was first recognized by Fenwick as long ago as 1880. Only since 1938, however, has the lesion been precisely localized to the body of the stomach. Early histological studies were restricted to small pieces of stomach and the findings were often vitiated by postmortem change. Faber and Bloch (1900) overcame the latter difficulty by instilling formalin through the stomach tube soon after death.

Magnus and I (1938) applied early formalin fixation to the study of stomachs in pernicious anemia. By the "Swiss roll" technique (cutting and rolling long strips of stomach from various regions), we were able to examine large areas and to define the nature and distribution of the lesion. The lesion is a remarkable one. To date, nothing quite like it has been found except in pernicious anemia. By means of photographs, we showed the thickness of the normal mucosa of the body of the stomach, with long tubular glands, which produce acid, pepsin, and (in man) probably the intrinsic factor of Castle. We also depicted the thin atrophic mucosa of the body of the stomach in pernicious anemia, showing how the normal glandular structure is replaced by low-grade "intestinal" epithelium.

The atrophy, which, in the body of the stomach, involves not only the mucosa but the muscular coats, stops abruptly at the margin of the pyloric region. In the pyloric gland area, both mucosa and muscle are of normal thickness and appearance.

Of interest in relation to the gastric lesion is the occurrence of benign adenomatous polyps. In one series of cases of pernicious anemia, the incidence of gastric polyps was as high as 7 per cent. Moreover, a follow-up of patients with gastric polyps shows that most have achlorhydria, while many have pernicious anemia or develop it later. There is no reason to believe that the polyps cause pernicious anemia or that pernicious anemia causes polyps. The two conditions seem to develop independently on the same soil, and either may precede the other by many years. The polyps, which may be single or multiple, arise not only from the atrophic mucosa of the body of the stomach but from the pylorus region also. The frequency with which these polyps undergo malignant change may account for some of the cases in which pernicious anemia and carcinoma of the stomach are found together.

We have found no evidence that the gastric lesion in patients with pernicious anemia and subacute combined degeneration is any more extensive than in uncomplicated pernicious anemia. We found a high incidence of subacute combined degeneration in a small series of cases of gastric polyposis, but this was probably fortuitous.

The atrophy persists despite prolonged liver therapy (Wood, 1951; Magnus and Ungley, unpublished) and is probably irreversible. Histologically, the lesion seems to be non-inflammatory. Although pernicious anemia is sometimes associated with a disorder of the pituitary or of the thyroid (either myxoedema or hyperthyroidism) there is no evidence that the gastric lesion is of endocrine origin. Nutritional deficiency may give rise to achlorhydria, but not, as far as we know, to gastric atrophy of the type found in pernicious anemia.

The racial and familial incidence of pernicious anemia, taken in conjunction with the peculiar nature of the lesion, suggest that the latter may be a genetically-determined abiotrophy.

Geographically, the disease occurs chiefly in North-east Europe and North America. The races most affected are Scandinavians and those of British stock. Chinese and Indians are affected extremely rarely. The incidence amongst the negroes in North America is much lower than in the white population.

In the affected races, there is a strong familial tendency. An example is shown in the family tree which represents the incidence of pernicious anemia and subacute combined degeneration in the Watson family (Ungley and Suzman, 1929). The inherited factor is not gastric atrophy, but a tendency to develop this atrophy in later life.

* This paper, illustrated with lantern slides, was presented at a special meeting of the Section on June 14, 1951. Some of the views expressed here are speculations rather than accepted facts. They are put forward merely as a working hypothesis to stimulate criticism and discussion.

† Royal Victoria Infirmary, Newcastle-upon-Tyne, Northumberland, England.

The incidence of pernicious anemia increases with age. This is not shown when cases are grouped simply into decades, but becomes obvious when they are related to the number of persons alive in each age group. The incidence of achlorhydria is high among the relatives of patients with pernicious anemia and this too increases with increasing age.

It is remarkable that we do not know the nature of the lesion underlying simple achlorhydria without anemia. Judging from the findings with histamine test meals, there is no difference in the degree of gastric defect in respect of total acid, pepsin, volume of juice or ability to excrete neutral red. One difference is that the gastric juice of patients with simple achlorhydria contains intrinsic factor, that is to say, when the juice is incubated with beef muscle or other source of extrinsic factor, the material is effective in pernicious anemia, whereas this is not true of juice from patients with pernicious anemia.

The gastric atrophy probably leads to pernicious anemia by a dual mechanism: (a) loss of Castle's intrinsic factor leads to impaired absorption of vitamin B_{12} from ingested foods, and thus to depletion of vitamin B_{12} from the tissues and from the blood; and (b) achlorhydria (and perhaps the loss of other constituents such as B_{12}-binding substances and enzymes) leads to a reduction of the anti-bacterial effect normally exerted by gastric juice. As a result, bacteria proliferate and migrate to higher levels of the small intestine. These bacteria, acting in an environment rendered abnormal by the lack of gastric acid and enzymes, are probably responsible for the production of a toxic factor or inhibitor (see below).

In addition, certain bacteria, *e.g.*, *B. coli*, in the small intestine may take up vitamin B_{12}, of which the host is thus deprived. I do not believe, however, that pernicious anemia can be explained solely on the basis of a nutritional deficiency.

Toxic and Haemolytic Aspects of Pernicious Anemia

The dramatic improvement in appetite and wellbeing, disappearance of pyrexia, the relief of sore tongue and gastro-intestinal disturbances often occur before the red cell count has altered appreciably. Relieving the anemia by transfusion does not have the same effect. These phenomena might be due either to relief of a nutritional deficiency or to the cessation of a toxic effect.

Even a complete and sudden cessation of erythropoiesis could not produce the very rapid drop in red cell count observed in some patients in severe relapse. Destruction of poorly-formed red cells is insufficient as an explanation, for in these exceptional cases even transfused cells from normal donors are rapidly eliminated (Ungley and Walker, unpublished). On the other hand, cells transfused during a remission or even during moderate or mild relapse seem to survive for a normal length of time (90 to 120 days). In six patients with excessive haemolysis (three with pernicious anemia, two with megaloblastic anemia of pregnancy, and one with sprue syndrome), there was a dramatic change to a normal rate of elimination, which in five cases occurred within two weeks of giving vitamin B_{12} or folic acid. One possibility is that vitamin B_{12} and/or folic acid prevented the production of an haemolytic agent or were concerned in its detoxication.

Rhoads *et al.* (1938) found that indol administered to dogs on a diet deficient in the vitamin-B complex had an haemolytic effect, whereas no such effect was observed in dogs receiving a normal diet.

It may be relevant, too, that the urinary excretion of certain phenolic compounds is excessive in relapse and becomes normal after treatment with liver extracts or vitamin B_{12} (Swendseid *et al.*, 1947; Abbott and James, 1950). Liver slices from rats deficient in folic acid failed to metabolize tyrosine completely until folic acid was added (Rodney *et al.*, 1949). Intermediary products of tyrosine metabolism include phenolic substances.

The existence of a substance which inhibits normal erythropoiesis in the plasma of patients suffering from pernicious anemia in relapse was demonstrated by Rusznyák *et al.* (1948), and has since been confirmed (Lajtha, 1950; Thompson, 1950). Such plasma not only inhibits the maturation of megaloblasts in cultures of megaloblastic marrow, but can even lead to the production of megaloblasts in cultures of normal marrow. The nature of the substance is unknown; after vitamin B_{12} therapy, it disappears. Its presence in cerebrospinal fluid suggests that it may be ultrafiltrable. It was not destroyed by heating for one to two hours at 56°C. (Lajtha, 1950).

The origin of the factor can only be surmised. Megaloblastic anemia associated with intestinal stenosis, blind loops or blind sacs, seems to occur only if a portion of gut is stagnant and infected. In experimental animals, there may be a long

latent period before the onset of anemia. A working hypothesis is that materials are formed in the stagnant loop which in some way interfere with the formation, absorption, or utilization of haematinic principles (Watson *et al.*, 1948). Ungley (1950) suggests that an inhibiting agent produced in the stagnant portion of gut is detoxicated in the intestinal wall or in the liver by (postulated) enzymes of which folic acid and/or vitamin B_{12} form the prosthetic groups. This leads to an increased demand for one or both nutrients, the stores of which are gradually depleted. When depletion reaches a certain level, detoxication fails and the animal suddenly becomes anemic and ill. In rats, at least, haemolysis was a feature of the disorder, which could be prevented by antibiotics (Toon and Wangensteen, 1950) and cured either by aureomycin or by folic acid (Witts, 1951).

In pernicious anemia, too, the inhibiting agent may arise in the small intestine, for bacteria flourish there in a medium rendered abnormal by the absence of gastric acid and enzymes. On this hypothesis, fluctuations in the production and detoxication of this agent could be responsible for spontaneous relapses and remissions.

The toxic agent could be responsible not only for the megaloblastic changes in the marrow but also for the glossitis and the damage to the nervous system.

Early lesions in the central nervous system in pernicious anemia are patchy in distribution and often related to blood vessels. They suggest the presence of a substance destructive of myelin rather than a simple lack of some essential. Subacute combined degeneration of the cord occurs in a surprisingly high proportion of patients with megaloblastic anemia due to stenosis or blind loops of small intestine, even though free hydrochloric acid may be present in the gastric secretion. It is therefore possible that intestinal bacteria play a part in inducing megaloblastic anemia and spinal degeneration in pernicious anemia and that their activities are offset by vitamin B_{12} (Witts, 1951).

Both vitamin B_{12} and folic acid are necessary for normal haemopoiesis. In pernicious anemia, although the real deficiency is of vitamin B_{12}, giving of folic acid is temporarily effective; perhaps it facilitates the utilization of remaining stores of vitamin B_{12}, the depletion of which is thereby accelerated. When depletion reaches a certain level, folic acid becomes ineffective; relapse supervenes, which may be haematological, lingual or neurological.

Absorption and Utilization of Vitamin B_{12}

The latest advances in this field are due largely to the work of two investigators; Lajtha, who developed the technique of culturing megaloblastic marrow, and Ross, who applied the *Euglena* assay to the determination of vitamin B_{12} in serum. I am fortunate in having the collaboration of Ross in my studies on intestinal absorption of vitamin B_{12}, and of R. B. Thompson, who in my laboratory has confirmed most of Lajtha's findings.

Free vitamin B_{12} added to marrow culture has no maturing effect on the megaloblasts, whereas vitamin B_{12} combined with a thermolabile substance in gastric juice *is* effective. The complex thus formed by admixture of gastric juice and vitamin B_{12} is microbiologically inactive. Heating splits off the vitamin and renders it available to the test organism, but destroys the megaloblast-ripening property of the complex.

Serum from normal persons and from treated patients with pernicious anemia contains bound vitamin B_{12} and is effective in marrow culture. Heating releases the vitamin and makes it available to the test organism, *Euglena gracilis*. Serum from patients with pernicious anemia contains little or none and is inactive in marrow culture. During treatment there is a close correlation between the level of bound vitamin B_{12} in serum and the state of maturation of red cell precursors in the bone marrow (Mollin and Ross, 1951).

Callender and Lajtha (1951) believe that the substance to which vitamin B_{12} becomes bound in serum is the same as Castle's intrinsic factor. But free vitamin B_{12} is effective even when administered parenterally to patients with pernicious anemia, who, in any case, secrete little or no intrinsic factor in their gastric juice. Callender and Lajtha therefore postulate an extra-gastric source of "intrinsic factor". The substance is not circulating in the plasma of patients with pernicious anemia, for such plasma does not potentiate the effect of vitamin B_{12} added to marrow cultures. Even normal serum is probably not a source of free intrinsic factor, for it has no potentiating effect when administered orally with vitamin B_{12} (Cox and Ungley, unpublished).

Where then does the binding take place? The clue, I think, is the difference in fate of orally-administered and injected vitamin B_{12}. When 100

μg. is injected intramuscularly, large amounts circulate free for about eight hours and much escapes in the urine. After eight hours, most of the vitamin B_{12} in serum is bound and urinary elimination is slight.

When large doses of vitamin B_{12}, *e.g.*, 3,000μg., are given orally to patients with pernicious anemia, the haemopoietic effects are equivalent to those expected from the injection of 20μg. to 40μg. and sometimes of 80 to 160μg. Yet very little escapes in the urine. The same is true after oral administration of large doses in normal persons. This is not due only to slower absorption, for the peak of elimination occurs at about the same time as after parenteral administration (Cuthbertson, 1951).

The suggestion is that the orally-administered vitamin B_{12} is effectively bound almost as quickly as it is absorbed.

The pattern of excretion after vitamin B_{12} is injected into the mesentery does not differ from that after intramuscular injection (Chalmers, Cuthbertson, Pegler *et al.*, 1951), suggesting that liver does not take up or modify large amounts of free vitamin B_{12}.

Experiments are in progress (with E. V. Cox, G. I. M. Ross and B. Schofield), in which free vitamin B_{12} is administered orally in animals or in patients undergoing laparotomy, to determine whether the level of bound vitamin B_{12} rises higher in the mesenteric and portal blood than in the hepatic and systemic blood. Results are conflicting and much more work is necessary, but at present our working hypothesis is still that vitamin B_{12} is bound in the wall of the intestine as it is absorbed. Should this prove to be correct, an intriguing possibility is that the substance which binds vitamin B_{12} is formed there under the influence of free vitamin B_{12} just as apoferritin is thought to be formed in the intestinal cells during the absorption of iron. When one considers the rôle of vitamin B_{12} in the synthesis of methyl groups, this hypothesis seems to be less improbable.

Bibliography

ABBOTT, L. D., & G. W. JAMES. 1950. J. Lab. & Clin. Med. **35:** 35.

CALLENDER, S. T. E. & L. G. LAJTHA. 1951. Blood. J. Hematol. In press.

CHALMERS, J. N. M., W. F. J. CUTHBERTSON, H. F. PEGLER, & Z. M. HALL. 1951. Internat. Congr. Clin. Pathol., London. Programme, p. 64.

COX, E. V. & C. C. UNGLEY. Unpublished.

CUTHBERTSON, W. F. J. 1951. In discussion of Internat. Cong. Clin. Pathol., London.

FABER, K. & C. E. BLOCH. 1900. Z. klin. Med. **40:** 98.

FENWICK, S. 1880. On Atrophy of the Stomach and on the Nervous Affections of the Digestive Organs. J. and A. Churchill, London.

LAJTHA, L. G. 1950. Clin. Sci. **9:** 287.

MAGNUS, H. A. & C. C. UNGLEY. 1938. Lancet, **234:** 420. Also unpublished work.

MOLLIN, D. L. & G. I. M. ROSS. 1951. Internat. Congr. Clin. Pathol., London. Programme, p. 63.

RHOADS, C. P., W. H. BARKER, & D. K. MILLER. 1938. J. Exp. Med. **67:** 299.

RODNEY, G., M. E. SWENDSEID, & A. L. SWANSON. 1949. J. Biol. Chem. **179:** 19.

RUSZNYÁK, I., S. LÖWINGER, & L. G. LAJTHA. 1948. Hung. Acta med. **1:** 1.

SWENDSEID, M. E., B. WANDRUFF, & F. H. BETHELL. 1947. J. Lab. & Clin. Med. **32:** 1242.

THOMPSON, R. B. 1950. Clin. Sci. **9:** 281.

TOON, R. W. & O. H. WANGENSTEEN. 1950. Proc. Soc. Exper. Biol. Med. **75:** 762.

UNGLEY, C. C. 1950. Proc. Roy. Soc. Med. **43:** 537.

UNGLEY, C. C. & M. M. SUZMAN. 1929. Brain **52:** 271.

UNGLEY, C. C. & W. WALKER. Unpublished.

WATSON, G. M., D. G. CAMERON, & L. J. WITTS. 1948. Lancet **255:** 474.

WITTS, L. J. 1951. Lancet **261:** 367.

WOOD, I. J. 1951. Brit. Med. J. **ii:** 823.

A more complete account of work on vitamin B_{12} with some two hundred references is given in a recent review (UNGLEY, C. C. 1951. Nutr. Abstr. Revs. **21:** 1.).

P-TECHNIQUE, A NEW METHOD FOR ANALYZING THE STRUCTURE OF PERSONAL MOTIVATION*

By RAYMOND B. CATTELL†

The dissection of human motivation is a very ancient art and in the last half-century, particularly through psychoanalysis, it has also acquired some claims to being a science. Few research psychologists, however, would accept as adequate the alleged pragmatic proof of the truth of psychoanalysis, and most, I think, would also agree that the attempts at experimental work on psychoanalytic and dynamic concepts have failed, by reason of certain systematic weaknesses, to be very conclusive.

If one seeks for the causes of this comparative failure, he will sooner or later be led to the conclusion that the major methodological weakness lies in the inability to define and measure precisely the individual "tensions" or forces about which the dynamic psychologist talks. What behaviors, in fact, do express the sex drive, the ego, or the super ego? How may one substantiate such an assertion as one that the patient is suffering from defective ego development, or that super-ego action has become excessive? The classical experimental method of control and quantitative observation of variables in single pairs practically never can be applied to the total organism in its natural life situation, and I think we achieve a mature perspective of our methodological difficulties only when we realize that a quite different and essentially wholistic approach must be made.

The clinician, of course, makes a wholistic approach, but it is not a quantitative one. In the last twenty years, however, a statistical method has developed, namely, multiple factor analysis, which enables us to get the relation in a global mass of variables with the precision of experiment, but without the classical experimentalists' procedure of control or manipulation, and also without their piecemeal atomicity of "pairs" of dependent and independent variables.

I do not claim that factor analysis is the complete answer necessary for a wholistic handling of the individual in his environment. Still less do I argue that it is yet free of certain limitations as a mathematical model or a practical statistical procedure. It lacks perfection, notably in its inability to deal with curvilinear relations and in its danger of confusing first and second order factors. It is, however, capable of solving problems to a first level of approximation, which we are otherwise quite unable to handle by scientific method, by reason of the defects of controlled experiment. Indeed, it does, in an explicit and quantitative fashion, with machine aids, precisely what most clinicians and sociologists are doing in their heads. They likewise observe a wide array of variables and look for signs of covariation, but they do so with fallible memories, intuition, and confusion!

The experiments I am about to describe began with this theoretical realization; but they were encouraged also by the practical success which factor analysis has achieved over the last fifteen years in structuring abilities and in determining personality dimensions of a non-dynamic, or, at least, a temperamental and general nature. These personality dimensions, it is true, have not yet received ample use and illustration in clinical psychology. The chief reason for this, *i.e.*, the chief reason, if I may say so, beyond the psychiatrist's ignorance of the meaning of the statistics, is that these factors are statements about the average person, whereas the clinician wants statements about the dynamics of a particular person.

In ordinary factor analysis, which has been called R-technique,[9] one correlates variables using the "individual difference" variance in a population of persons. The resulting factor loadings are statements concerning the extent to which particular variables are associated with a given factor for that sample of the population, and, by inference, for the population generally. In personality theory, the pattern of loadings for such a factor would be said to define a common trait. The uniqueness of an individual,[1] it is true, can be expressed in terms of a unique combination of such R-technique factors, but the clinician is right in asserting that this does not describe all the uniqueness in which he is interested, and this is particularly true of dynamic, motivational traits. For example, an R-technique factorization of interests

* This paper was presented at the meeting of the Section on October 15, 1951.

† Laboratory of Personality Assessment and Group Behavior, University of Illinois, Urbana, Illinois.

shows that, for the average adolescent, interest in attending movies is highly loaded in a factor which can be identified as the sex drive,[5, 7] but we should not like that common factor loading to be unquestionably applied to us as individuals whenever we state an intention to go to the movies. In the chief applied psychology of motivation, namely, in clinical psychology, this objection applies *a fortiori*, for the patient is, by definition, motivationally queer.

Faced with this defect of R-technique factorization, I suggested in 1946[4] a new experimental design for factor analysis, called P-technique, the factorization of the single person. The individual is measured on much the same sort of variables as one would use in an R-technique personality study, but the testing is repeated from day to day for perhaps 100 days. If a measure of interest in food, for example, rises and falls over this series of occasions, sympathetically with a measure of anxiety, for example, then we conclude that this interest in eating is partly an expression of anxiety, or *vice versa*. Indeed, we correlate the variables to get a correlation matrix similar to an R-technique matrix, except that it is specific for the individual and its entries are constituted by a series of occasions instead of a series of people. When this matrix is factored and rotated for simple structure, we should expect, on theoretical grounds, that the factors would correspond to unitary traits as they are patterned in that individual, though we should also expect these to have some resemblance, in outline, to common source traits.

Before citing the experimental verdicts on these expectations, I would like to point out to the statistician the peculiar fact that we are here trying to use as meaningful variance what has previously been thrown away as error. We have, as it were, extracted a little more pure metal from the dross of accident. Of course, it has always been accepted that the variation from one testing to another in a psychological measurement, which psychologists assess in the reliability coefficient, is partly function fluctuation,[11] as well as partly true experimental error; but some psychologists of repute declined to believe at first that P-technique would yield anything but a factorization of error. Actually, if function fluctuations had proved too small a fraction of the total "error variance," we could have brought it in more strongly by combining factor analysis with experimental control, stimulating the subject from occasion to occasion by various conditions, but this proved unnecessary.

The outcome of P-technique research in regard to general personality factors is now just sufficiently explored by four published researches[2, 3, 8, 12] to permit us the generalization that it does yield the same general factors as R-technique, though with some loadings idiosyncratic to the subject and with a different order of mean magnitude of variance of the factors. For example, general intelligence is a large factor in individual differences, but a barely perceptible one in P-technique, because it seems to vary so little from day to day.

However, our special interest in this article is not P-technique in general, but P-technique in relation to the peculiar potency which has been found for it in structuring dynamic traits, so this glance at the general background must suffice. With so much to cover, I shall not pause to discuss the precise definition of a dynamic trait, though I believe such is possible,[4] but shall assume that we mean desires, interests, attitudes, drives, sentiments and complexes.

It is hard for an honest psychologist, if such there be, to confess publicly how little of the dynamic structure of the average personality is scientifically known and agreed upon, as distinct from clinically presumed. Psychologists cannot even agree about the number and nature, even the existence or non-existence, of drives. If drives exist as unitary traits, however, surely the factor analysis of dynamic variables ought to reveal them. It might be expected also to reveal patterns corresponding to those organized systems of attitudes which we call sentiments and complexes. Two R-technique factorizations,[6, 7] initially using a set of 50 diverse attitudes, have already been published, showing that factors corresponding to the chief hypothesized drives emerge and that, at any rate, one sentiment, the self-sentiment pattern, can also be detected. It seemed desirable at this point to reproduce the same variables and make a P-technique factorization, in order that the similarity of the patterns could be tested exactly. The drives are so universally human, even mammalian,[5] that we should expect the same patterns to emerge. At the same time, we should expect individual peculiarities of loading in the P-technique analysis which would agree with clinical perceptions[10] of special fixations of the drives.

Parenthetically, I shall use the term *erg*, from the Greek root for work or energy,[5] because it is our hypothesis that the main patterns with which we are dealing are sources of energy or reactivity

to stimuli.[5] This term is used instead of drive, propensity, need, or tension, because these "borrowed," popular terms drag in all manner of popular misunderstandings. It is our intention to make a clean start with a new method, and to use an operational concept defined initially as *a unitary pattern in dynamic traits found by factor analysis*. Our hypothesis ultimately extends further, however, in supposing that research may also demonstrate that this pattern is connected with an innately-given final goal.

In the present study, we took the ergic patterns already demonstrated in the two R-technique studies and represented each by at least two attitudes, namely, those most highly loaded in the given factor. This is the minimum necessary to locate a factor; more would have made the length of the individual testing too great. We also took three marker variables for the only metanerg or sentiment previously found, namely, the self-regarding sentiment. By way of illustration, the escape or fear erg was represented by two attitudes: "I want America to get more protection from the terror of the atom bomb," and "I want never to be an inmate in a mental hospital." The above mentioned self sentiment was represented by the following three attitudes: "I want never to do anything that will damage my sense of self respect," "I want a will power sufficient to control my emotions," and "I want to command a good reputation among people in my circle." These choices, it should be noted, have passed two tests. First, they are attitudes which, on clinical, psychological grounds, would be expected to involve a great deal of the erg in question. That is to say, their content indicates either fear, sex, or parental protective intention, *et cetera*. Secondly, the hypothesis has already been checked by the R-technique research, where they have been found to come together in a factor with that general meaning, and in no other factor. As a typical R-technique factor, we will take that which we have interpreted as the parental-protective erg, similar to Murray's and McDougall's propensity of the same name.

Of the four attitudes separating themselves by their significant loadings from 50 here, three were originally put in to mark this erg (Table 1). The patriotic attitude also seems to be largely protective. Incidentally, an attitude could, by hypothesis, fall both in an erg and a sentiment, but, on an average, each could account for only half its variance, and, for greater research clarity, we picked twenty attitudes relatively pure in given ergs. An example of a pattern not anticipated in our hypotheses, yet fitting psychoanalytic notions, is shown in the factor which we have called regressive play or narcissism.[6]

As to the method of measuring the strength of each attitude variable experimentally, it was our intention from the beginning of this work to avoid the purely verbal, self-rating basis on which all too much attitude research has been based, and to this end, a number of separate studies were made on a dozen or more objective methods, involving reaction times, P.G.R. measurements, selective memory effects, *et cetera* (see bibliography of bibliographical reference 6). Having obtained a number of measures which correlate positively together for each and every attitude, we took as the attitude strength that which was common to the various measures. The standard verbal opinionaire method was by no means always one most saturated with the common motivation factor and was in any case used in these researches as one of several devices, the scores of which were added to give the motivation strength measurement. In the P-technique study, the twenty attitudes were measured each day by each of three devices, namely, a preference test, a retroactive inhibition test, and a fluency test. The preference test is like the animal choice box, a paired comparison of attitudes in all possible pairs, asking the subject which would he rather do or have done. The memory test tested recall for the attitude statements, and the fluency test measured the number of arguments the subject could imagine for the attitude in question. The reliabilities of these tests were respectively .73, .17, and .72.

The subject used for this trial of P-technique

TABLE 1

FACTOR FROM R-TECHNIQUE STUDY[4] HYPOTHESIZED AS PARENTAL, PROTECTIVE ERG

Variable No.	*Attitude Defined*	*Loading in Factor I*
42	I want to continue to live in America, the most congenial country for me in people and ideals.	0.53
50	I want to be able to insure for my children the best education that they could possibly have.	0.48
43	I want my parents never to be lacking the necessities of comfortable living.	0.44
46	I want to be able to do more for children who are sick, or poor or uncared for, anywhere in the world.	0.42

was a normal young man of 23, a student in drama, currently rehearsing for a college play, which was put on midway through the 80-day test period. Another event of some importance, namely, a serious accident to his father, also occurred in the test period. He was given clinical type interviews and also kept a personal diary over the whole period. At the end, the attitudes were correlated and it was found that nine factors substantially accounted for the inter-correlations. I would like to stress, in view of the ensuing interpretations, that these factors were rotated blindly for simple structure, *i.e.*, without knowledge of psychological meaning of the variables. A quite definite simple structure was found in this P-technique, as described elsewhere[8] and typically illustrated in FIGURE 1.

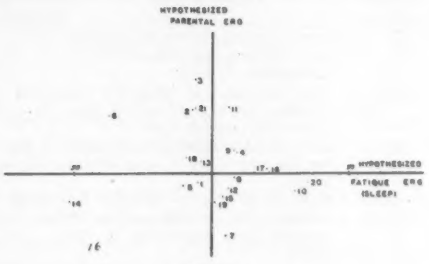

FIGURE 1

ILLUSTRATION OF TWO FACTORS IN SIMPLE STRUCTURE

FACTOR OF SLEEP

Variable No.	*Attitude Defined*	*Loading in Factor 9*
41	I do not want to be able to spend somewhat more on drinking and smoking.	−51
6	I do not want to take an active part in athletics.	−37
20	I want more time to enjoy sleep and rest.	35
10	I want to listen to music.	30

FACTOR OF PARENTAL PROTECTIVENESS

Variable No.	*Attitude Defined*	*Loading in Factor 3*
3	I want to help the distressed wherever they are.	34
11	I want to know more science.	25
21	Sessions after father's accident.	24
2	I want my parents never to be lacking the necessities of a comfortable living.	23

Evidence is given in the original study[8] for the factors found being identifiable as the following ergs and sentiments: (1) the escape or fear erg; (2) the parental, protective erg; (3) the self-assertive erg; (4) the mating or sex erg; (5) the erg of curiosity; (6) the erg of sleep; (7) the pattern of regressive, narcissistic play; (8) the self-sentiment; and one further factor of too little variance to be interpreted.

It is next of interest to examine the degree of invariance of these factor patterns and, particularly, to compare the P-technique with the R-technique pattern. The degree of invariance can only be assessed at present from two existing R-technique studies with the same variables. In FIGURE 2, the same variables are super-posed in one drawing for all three factorizations, the ergs taken for illustrations being those of mating and curiosity.

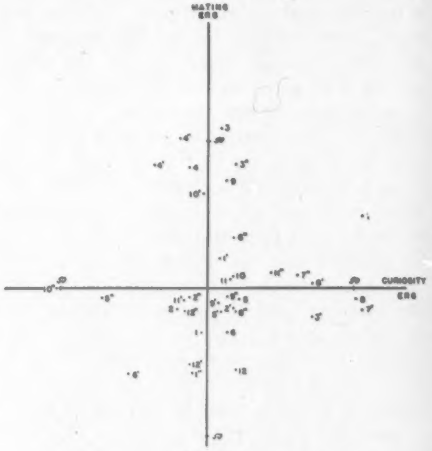

FIGURE 2

TWO R-TECHNIQUE STUDIES AND ONE P-TECHNIQUE STUDY SUPERPOSED

Most Highly Loaded Variables

3. I like to go to a good movie or play every week or so.
4. I want to make love to a woman I find beautiful.
7. I want to listen to music.
8. I want to know more science.

The R-technique variables are shown by a plain and a prime number and the P-technique is shown by a double prime number. Thus the attitude interest number 4, which refers to "I want to make love to a woman I find beautiful," is shown in three adjacent positions on the upper left. Similarly, the sevens group high on the curiosity erg. The eights show some discrepancy in that though

"interest in science" is motivated powerfully by curiosity in the average man, as shown by the two R-technique studies, it was not much so motivated in the individual studied in the P-technique. In fact, its largest variance with him was in the self-sentiment, for reasons we shall soon see. Again, the simple structure is very clear.

Although this level of agreement is maintained throughout the factors found in the three studies, there are some few striking discrepancies, notably between the R-technique studies on the one hand and the P-technique on the other. An examination of these should throw light on the capacity of P-technique to reveal unique dynamic attachments. For this purpose, I have taken again a pattern not previously illustrated, namely, the self-sentiment and have included only the variables common to the two studies. In FIGURE 3 (taken from bibliographical reference 8), we have this one factor, not two; the loadings on the unique form of it being plotted against those of the same variables on the common source trait of R-technique.

Eleven of the variables are tolerably on a straight line, indicating similar loading pattern in the two studies, but three, which have been encircled, are different to a marked degree. This analysis shows that, for the given individual, interest in science and in music are much more involved in the self-regarding sentiment than is commonly the case, while heterosexual love is also slightly on the negative side of self-regard, instead of somewhat positively involved in self regard as in the average person. So far as it is possible to represent our clinical investigations in a few words, we find that this young man was brought up in a family in which his intelligence was educated in the direction of scientific endeavor. His inclinations, however, turned out to be in favor of music and drama. He had felt guilty of taking a dilettante interest in music as an escape from more serious work. Accordingly, it seems that, in spite of his inclinations, his self-sentiment, which, in our theory of personality structure, includes the superego, regarded indulgence in music as something to be avoided and a knowledge of science as something which any self-respecting person ought to cultivate.

Not only does the P-technique analysis thus permit an estimate of the extent to which various ergs and sentiments are involved in a particular attitude, in what amounts to a quantitative psychoanalysis, but it also offers, later, a measure of the total excitation strength of any given drive from occasion to occasion. Our original assumption had been that the covariation on which the method depends for the revelation of connections, arises from two sources: (1) internal physiological fluctuations, and (2) stimulus situation variations. To test this we estimated the strength of each drive on each occasion by adding together the attitudes in which it is most highly loaded, and plotted, in the original presentation,[8] the course of each ergic potency through the 80 days of the experiment. The most marked change of level of any erg occurred in the parental, protective drive after the serious accident to the young man's father. It was as if the whole level of pitying and cherishing behavior was stimulated to a new level. Other changes are more temporary and even cyclic, suggesting physiological causes for increased reactivity.

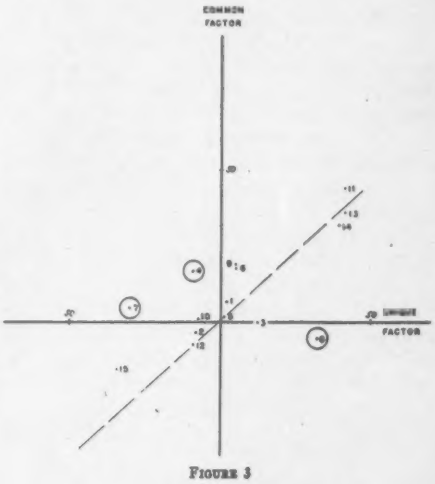

FIGURE 3

COMPARISON OF P- AND R-TECHNIQUE DEFINITIONS OF SELF REGARD

Chief Attitude Variables Involved

4. I want to make love to a woman I find beautiful.
7. I want to listen to music.
8. I want to know more science.
9. I want America to get more protection against the atom bomb.
11. I want never to do anything that will damage my sense of self respect.
13. I want a will power that will ensure good control of my mental processes and emotions.
14. I want to command a good reputation among people in my circle.
15. I want more time to enjoy my own company, to sleep and rest.

To summarize, or, at least, to state what seem the most important issues raised in this survey of the relation of P-technique to dynamic psychology generally:

1. Factor analysis, properly used, is capable of structuring dynamic traits just as effectively as cognitive or any other behavior variables, both in R- and P-technique forms.

2. When it does so, the most outstanding unitary traits seem to be the long debated drives, or ergs, as we have called them, and these show up with essential similarity of pattern in both R- and P-technique.

3. P-technique is, however, alone in being capable, in principle, of yielding unique dynamic trait structure, that is, the particular investments and conflicts of the ergs in the life of the individual. The experimental evidence here offered suggests that it does this not only in principle but with practical effectiveness. If further experiment bears this out, and improves the reliability of objective measures of interest, this method offers a superior method to the present free-associative techniques of psychoanalysis, because it is quantitatively precise and proceeds to its analytical conclusions by a calculating machine and explicit principles, instead of by the uncertainties of art and intuition. Nevertheless, a preliminary exploration of a clinical case by ordinary clinical questioning would be necessary in order to decide which symptoms and fixations should be entered as unique variables, along with the common "marker" variables introduced from R-technique to locate the primary ergs. While the method is thus a serious challenge to psychoanalysis as a method of diagnosis, it does not claim any rôle in therapy, except in so far as the improved objectivity and insightfulness of its diagnosis would permit a more effective handling of resistances, *etc.*, in the re-learning process.

4. The specification equations obtained do not directly estimate the absolute strengths of various ergic satisfactions in a given symptom or course of action, but rather the contribution of ergic variance to symptom variance.

Bibliography

1. Allport, G. W. 1937. Personality, A Psychological Interpretation. Henry Holt & Co., New York.
2. Cattell, R. B., A. K. S. Cattell & R. M. Rhymer. 1947. P-technique demonstrated in determining psycho-physiological source traits in a normal individual. Psychometrika **12:** 267–288.
3. Cattell, R. B. & L. B. Luborsky. 1950. P-technique demonstrated as a new clinical method for determining personality and symptom structure. J. Gen. Psychol. **42:** 3–24.
4. Cattell, R. B. 1946. The Description & Measurement of Personality. World Book Co., New York.
5. Cattell, R. B. 1950. Personality: A Systematic Theoretical & Factual Study. McGraw-Hill, New York.
6. Cattell, R. B. 1950. The discovery of ergic structure in man in terms of common attitudes. J. Abn. & Soc. Psychol. **45:** 598–618.
7. Cattell, R. B. & A. Miller. 1952. A confirmation of the ergic and self-sentiment patterns among dynamic traits, as determined by R-technique. Brit. J. Psychol. In press.
8. Cattell, R. B. & P. Cross. Comparison of the ergic and self-sentiment structures found in dynamic traits by R- & P-techniques. In press.
9. Cattell, R. B. 1951. Factor Analysis: An Introduction & Handbook. Harper Bros., New York.
10. Freud, S. 1933. New Introductory Lectures on Psychoanalysis. Norton, New York.
11. Vernon, P. E. 1948. The Measurement of Abilities. Univ. of London Press, London.
12. Williams, H. V. M. A determination of psychosomatic functional unities in personality by means of P-technique. In press.

ELEMENTARY L_1-SPACES*

By L. A. MacCOLL†

1. *Introduction.* The somewhat special L_1-spaces with which we are concerned here can be described as follows:

a. Each of the spaces is a set of real-valued measurable functions of a real variable t, defined over the infinite interval $(-\infty, \infty)$. Each of the functions is absolutely integrable over the infinite interval. Two functions which differ only on a set of measure zero are considered to be identical.

b. The set of functions constituting a space is closed under the operations of multiplication by real constants and addition.

c. The distance, $d(f_1(t), f_2(t))$, between two functions, $f_1(t)$ and $f_2(t)$, belonging to a space is defined by the formula:

$$d(f_1(t), f_2(t)) = \int_{-\infty}^{\infty} | f_1(t) - f_2(t) | \, dt.$$

These L_1-spaces are important in various parts of pure and applied mathematics. Recently, they have been used in connection with certain problems arising in communication engineering. It is desirable, therefore, that the properties of the spaces be studied in some detail. Although most of the L_1-spaces coming within the scope of the above definition are quite difficult to study, some of the spaces can be discussed rather easily. It is with these elementary L_1-spaces that the present paper deals.

In sections 2–5 of this paper, we shall consider a particularly simple two-dimensional L_1-space, and section 6 will be devoted to a brief discussion of the analogous three-dimensional space. In the concluding section, we shall consider a few of the less simple two-dimensional spaces.

2. *The L_1-space S_0^2.* Let $u(t)$ and $v(t)$ be two particular linearly independent functions which satisfy the conditions stated in section 1, and which have the following additional properties:

(a) $$u(t)v(t) \equiv 0,$$

(b) $$\int_{-\infty}^{\infty} | u(t) | \, dt = \int_{-\infty}^{\infty} | v(t) | \, dt = 1.$$

If distances are defined as stated in section 1, the set of all functions of the form:

$$f(t) = xu(t) + yv(t),$$

where x and y are arbitrary real constants, is a two-dimensional L_1-space. We shall denote this space by the symbol S_0^2.*

Henceforth, a function belonging to S_0^2 will be called a point of S_0^2, and the corresponding coefficients x and y will be called the coordinates of the point. If we also interpret x and y as the rectangular coordinates, relative to a fixed set of axes, of a point in a Euclidean plane E^2, we have established a homeomorphism between S_0^2 and E^2. This homeomorphism makes it possible to discuss the geometry of S_0^2 in terms of figures drawn in E^2.

Let $f_1(t)$, with the coordinates (x_1, y_1), and $f_2(t)$, with the coordinates (x_2, y_2), be two points of S_0^2. In virtue of the properties of $u(t)$ and $v(t)$, we have the relation

$$d(f_1(t), f_2(t)) = | x_1 - x_2 | + | y_1 - y_2 | .$$

The following fundamental theorem can be proved by a straightforward argument, which we omit for the sake of brevity.

Theorem 1. In order that a point transformation $x' = \phi(x, y), y' = \psi(x, y)$ in S_0^2, where the functions ϕ and ψ are of class C^1, shall leave all distances invariant, it is necessary and sufficient that the transformation be of one of the forms:

(i) $$x' = a \pm x, \qquad y' = b \pm y;$$

(ii) $$x' = a \pm y, \qquad y' = b \pm x.$$

Here a and b are arbitrary constants, and the ambiguous signs are independent.

Stated in terms of the geometry of E^2, a transformation of the required kind is a translation, a quadrantal rotation, a reflection in a coordinate axis, or a product of two or more of these special transformations.

If a rotation is defined as a point transformation (of class C^1) which leaves one point and all distances invariant, Theorem 1 implies that S_0^2 does not admit of arbitrarily small rotations.

* This paper was presented at a meeting of the Section on October 19, 1951.

† Bell Telephone Laboratories, Inc., Murray Hill, N. J.

* Strictly speaking, we get different spaces by choosing the basic functions $u(t)$, $v(t)$ in different ways. However, all of the spaces so obtained have the same geometry, and can be considered abstractly as being identical.

If certain conditions of a familiar kind are satisfied, an equation of the form $F(x, y) = 0$ represents a curve in S_0^2. The only curves which we shall consider for the moment will be continuous curves consisting of finite sets of arcs, each arc being representable by an equation of one of the forms $y = f(x)$, $x = g(y)$, where $f(x)$ and $g(y)$ are functions possessing absolutely integrable derivatives. The length $L(\Gamma)$ of such a curve Γ is naturally defined by the formula

$$L(\Gamma) = \int_\Gamma (|\,dx\,| + |\,dy\,|).$$

The following theorem, the proof of which is obvious, plays a fundamental role in the geometry of S_0^2.

Theorem 2. If two points (x_1, y_1), (x_2, y_2) *are such that* $x_1 = x_2$ *or* $y_1 = y_2$, *there is a unique curve of minimum length joining the points (namely, in terms of the geometry of* E^2, *the straight line segment joining the points). If* $x_1 \neq x_2$ *and* $y_1 \neq y_2$, *every curve joining the two points on which* dy/dx *does not change sign has a length equal to the distance between the points, while every other curve joining the points has a length greater than that distance.*

In general, therefore, there is no unique geodesic joining two points of S_0^2. Such a geodesic does exist, however, if the two points lie on a line parallel to one of the preferred coordinate axes. In this way, the preferred coordinate systems receive an intrinsic geometrical characterization.

3. *Two problems concerning distances in* S_0^2. We define the circle with center (x_0, y_0) and radius r to be the set of all points which are at the distance r from (x_0, y_0). This circle is represented analytically by the equation

$$|\,x - x_0\,| + |\,y - y_0\,| = r,$$

and it is represented graphically in E^2 by the square having the vertices $(x_0 \pm r, y_0 \pm r)$.

Problem 1. We consider the straight line L represented by the equation $y = mx + b$, and a point P: (x_0, y_0) which does not lie on L, and we seek the point of L which is at the minimum distance from P.

We construct the family of circles having P as center, and note the circle of minimum radius which has a point in common with L. We see immediately that if $|\,m\,| < 1$, the point of L having the abscissa x_0 is the required point, and that if $|\,m\,| > 1$, the point of L having the ordinate y_0 is the required point. If $|\,m\,| = 1$, all points of L between the point having the abscissa x_0 and the point having the ordinate y_0 are equidistant from P, and every other point of L is at a greater distance from P.

Problem 2. Let a and b be positive numbers, and consider the set A of points (x, y) which are equidistant from the points $(a, 0)$, $(0, b)$. A is represented by the equation

$$|\,x - a\,| + |\,y\,| = |\,x\,| + |\,y - b\,|,$$

and the properties of the locus can be determined readily by a study of this equation.

We find that if $a > b$, A is represented in E^2 by the broken line consisting of

(i) the part of the line $x = (a - b)/2$ on which $y \leq 0$,

(ii) the part of the line $y = x - (a - b)/2$ on which $0 \leq y \leq b$,

(iii) the part of the line $x = (a + b)/2$ on which which $y \geq b$.

On the other hand, if $a = b$, we obtain the rather surprising result that A is represented in E^2 by the point set consisting of

(iv) the region $x \leq 0$, $y \leq 0$,

(v) the region $x \geq a$, $y \geq a$,

(vi) the part of the line $y = x$ on which $0 \leq x \leq a$.

The fact that in this case A is two-dimensional is of considerable importance in some of the applications.

The set of points equidistant from *any* two points of S_0^2 can be determined easily by using the special results just stated and Theorem 1.

4. *Measurement of angles in* S_0^2. We can define a measure of angles in S_0^2 in a way which is entirely similar to that used in Euclidean geometry. Thus, let OA and OB be two rays proceeding from a point O. We draw a circle of radius R with O as center, and denote by S the length of the arc of the circle intercepted by the rays. Then we take the ratio S/R as the measure of the angle between the rays. If $S/R = 1$, we call the angle a radian.

Since the ratio of the circumference of a circle to its radius is obviously 8, the total angle about a point is 8 radians.

Many of the elementary theorems concerning angles in S_0^2 are essentially similar to theorems concerning angles in Euclidean geometry. Thus,

for example, the sum of the angles of a triangle is 4 radians. If we define perpendicular lines to be lines which intersect at an angle of 2 radians, *i.e.*, one fourth of the total angle about a point, we find that two lines are perpendicular, if, and only if, the corresponding lines in E^2 are perpendicular in the Euclidean sense.

If we define a square to be a quadrilateral having equal angles and sides of equal length, we find that a quadrilateral is a square, if, and only if, the corresponding figure in E^2 is a square in the Euclidean sense. We observe that if the diagonals of a square are parallel to the preferred coordinate axes, the square is a circle!

At first sight, these simple examples may suggest that all that we have done is introduce a new unit for the measurement of angles. This is not the case, however. In general, two equal angles in S_0^2 (in E^2) correspond to two unequal angles in E^2 (in S_0^2).

5. *The curvature of a curve in* S_0^2. Let Γ be an oriented curve in S_0^2. We denote the arc length along Γ from a fixed reference point P_0 to a variable point P by the symbol s, the arc length being reckoned with the proper sign in the usual way. We denote the angle between the positively oriented tangent to Γ at P and the positive x-axis by the symbol $\theta(s)$. Then we define the curvature, γ, of Γ at P by the equation $\gamma = \theta'(s)$.

We shall prove the following theorem:

Theorem 3. If a curve Γ *in* S_0^2 *is represented by the equation* $y = y(x)$, *where the function* $y(x)$ *is of class* C^2, *and if* Γ *is oriented so that the positive sense is that of increasing values of* x, *the curvature of* Γ *at the typical point is given by the formula*

$$\gamma = \frac{2y''(x)}{[1 + |y'(x)|]^3}.$$

Consider the line

$$Y = y'(x)X, \tag{1}$$

where X and Y are the running coordinates. If $y'(x) > 0$, the line (1) intersects the line $X + Y = 1$ in the point with the coordinates

$$X = \frac{1}{1 + y'(x)}, \qquad Y = \frac{y'(x)}{1 + y'(x)}.$$

Then it follows from our definition of the measure of angles that

$$\theta = \frac{2y'(x)}{1 + y'(x)} \tag{2}$$

On the other hand, if $y'(x) < 0$, the line (1) intersects the line $Y = -1 + X$ in the point with the coordinates

$$X = \frac{1}{1 - y'(x)}, \qquad Y = \frac{y'(x)}{1 - y'(x)},$$

and we have the relation

$$\theta = \frac{2y'(x)}{1 - y'(x)}. \tag{3}$$

It follows from (2) that we have

$$\frac{d\theta}{dx} = \frac{2y''(x)}{[1 + y'(x)]^2}.$$

Since when $y'(x) > 0$ we have

$$\frac{ds}{dx} = 1 + y'(x),$$

it follows that when $y'(x) > 0$, we have the relation

$$\gamma = \frac{2y''(x)}{[1 + y'(x)]^3}.$$

Similarly, it follows from (3) that when $y'(x) < 0$ we have

$$\gamma = \frac{2y''(x)}{[1 - y'(x)]^3}.$$

Combining the two results, we have the conclusion stated in the theorem.

It is interesting to determine the curves which have constant curvature. Obviously, it will suffice to determine the curves for which $\gamma = 1$, for all other curves of constant curvature can be obtained from these by magnifications and reorientation. We determine these special curves by solving the differential equation

$$y'' = \tfrac{1}{2}(1 + |y'|)^3.$$

The work is straightforward, and we shall confine ourselves to stating the result in the form of the following theorem.

Theorem 4. Any curve with constant curvature 1 is obtained by subjecting a certain special curve Γ_0 *to a translation.* Γ_0 *is composed of the parabolic arc*

$$\Gamma_0^1 : y = 1 - x - 2\sqrt{1 - x}, \qquad 0 \leq x \leq 1$$

and of the three arcs which are obtained from Γ_0^1 by reflections in the coordinate axes. It is assumed here that Γ_0 is oriented so that the positive sense of description is counterclockwise.

If we denote the Euclidean curvature of the curve $y = y(x)$ by the symbol γ_e, so that

$$\gamma_e = \frac{y''}{(1 + y'^2)^{3/2}},$$

we have the relation

$$\frac{\gamma}{\gamma_e} = 2\,\frac{(1 + y'^2)^{3/2}}{(1 + |y'|)^3}.$$

From this, it follows that if y' is zero or infinite, we have $\gamma = 2\gamma_e$; and if $y' = \pm 1$, we have $\gamma = \gamma_e/\sqrt{2}$.

In particular, the Euclidean circle $x^2 + y^2 = 1$ has curvature 2 at the points $(\pm 1, 0)$, $(0, \pm 1)$, and curvature $1/\sqrt{2}$ at the points $(\pm 1/\sqrt{2}, \pm 1/\sqrt{2})$.

6. *The three-dimensional space S_0^3.* Let $u(t)$, $v(t)$, $w(t)$ be three particular functions satisfying the conditions stated in §1, and having the following additional properties:

(a) $$u(t)v(t) \equiv v(t)w(t) \equiv u(t)w(t) \equiv 0,$$

(b) $$\int_{-\infty}^{\infty} |u(t)|\,dt = \int_{-\infty}^{\infty} |v(t)|\,dt = \int_{-\infty}^{\infty} |w(t)|\,dt = 1.$$

If distances are defined as stated in §1, the set of all functions of the form

$$f(t) = xu(t) + yv(t) + zw(t),$$

where x, y, z are arbitrary real constants, is a three-dimensional L_1-space, which we shall denote by the symbol S_0^3. Obviously, S_0^3 is the natural three-dimensional analogue of the space S_0^2 which we have been considering.

We call a function belonging to S_0^3 a point of S_0^3, and we call the coefficients x, y, z the coordinates of the point. As in the two-dimensional case, we can set up a natural homeomorphism between S_0^3 and a three-dimensional Euclidean space E^3; and we can discuss the geometry of S_0^3 in terms of figures drawn in E^3.

The distance between two points of S_0^3 is given by the self-explanatory formula

$$d(f_1(t), f_2(t)) = |x_1 - x_2| + |y_1 - y_2| + |z_1 - z_2|.$$

We define the sphere with center (x_0, y_0, z_0) and radius r to be the set of all points which are at the distance r from the center. The sphere is represented in E^3 by a regular octahedron, having its center at (x_0, y_0, z_0) and having its diagonals (of length $2r$) parallel to the coordinate axes.

We define a circle in S_0^3 to be a plane curve such that all points of the curve are at the same distance from a fixed point in the plane of the curve. We get a circle by taking a suitable sphere and intersecting it with a suitable plane passing through the center of the sphere. *We observe that a circle is in general a six-sided polygon, although the circle degenerates into a quadrilateral for certain special positions of its plane.*

A straightforward, but somewhat complicated calculation leads to the following theorem.

Theorem 5. Let p and q be non-negative real numbers. A circle of radius R lying in any plane of the family $z = px + qy + \text{const.}$ has the circumference C given by the formula

$$\frac{C}{R} = 6 + \frac{2p\,|1 - q|}{(p + 1)(p + q)} + \frac{2\,|p - q|}{(p + 1)(q + 1)} + \frac{2q\,|1 - p|}{(q + 1)(p + q)}.$$

As p and q vary, C/R assumes all values between 6 and 8 inclusive.

Whereas all planes in E^3 have the same geometry, these properties of circles show that different planes in S_0^3 have essentially different geometries. This feature of the geometry of S_0^3 makes the study of this space awkward and difficult. We shall not pursue this study any further at this time.

7. *Other two-dimensional L_1-spaces.* If we omit the condition $u(t)v(t) \equiv 0$ from the definition of S_0^3, we get a variety of more general two-dimensional L_1-spaces, which we shall denote by the generic symbol S^2. Some of these S^2-spaces are much more important practically than is S_0^2. Unfortunately, however, they are also much more difficult to study. We shall confine our discussion of these spaces to giving one general theorem and a few remarks concerning the circles in these spaces.

The proof of the following theorem is obvious.

Theorem 6. The circle in S^2 with center (0, 0)

and radius 1 is represented in E^2 by a closed convex curve which is symmetrical with respect to the origin, and which passes through the points (1, 0), (0, 1).

It should be noted that a similar, and equally obvious, theorem holds concerning $(n - 1)$-dimensional hyperspheres in a space S^n, which is the n-dimensional analogue of an S^2.

Dropping the restriction $u(t)v(t) \equiv 0$ allows the functions $u(t)$ and $v(t)$ to "overlap." Some indication of the nature of the effects of the overlapping can be obtained from a consideration of the simplest case, the case in which $u(t)$ and $v(t)$ are defined as follows:

$$\begin{aligned} u(t) &= 1 \text{ for } 0 \leq t \leq 1 \\ &= 0 \text{ for all other } t, \\ v(t) &= 1 \text{ for } \alpha \leq t \leq \alpha + 1 \\ &= 0 \text{ for all other } t, \end{aligned}$$

where α is a positive number less than 1. An elementary calculation shows that in this S^2 the circle with center (0, 0) and radius 1 is the polygon whose vertices are the points (0, 1), (1, 0), $((2\alpha)^{-1}, -(2\alpha)^{-1})$, and the points which are symmetrical to these with respect to the origin.

The fact that all of the circles that we have encountered so far are rectilinear polygons is merely a consequence of the especially simple forms of the basic functions, $u(t)$ and $v(t)$, that we have chosen. When we proceed to less simple basic functions, we find that the circles in an S^2 cease, in general, to be rectilinear polygons. In one rather typical case, which has been examined in detail, a circle is a closed convex curve composed of two segments of straight lines and two curved arcs.

*SECTION OF OCEANOGRAPHY AND METEOROLOGY**

CLOUD SEEDING BY MEANS OF DRY ICE, SILVER IODIDE, AND SODIUM CHLORIDE†

By IRVING LANGMUIR‡

The circulation of the atmosphere is primarily due to the non-uniform solar heating of the earth and the radiation from the upper part of the atmosphere. When clouds form, heat is liberated by the condensation of the moisture. Most clouds soon evaporate so that the heat from condensation is balanced by the cooling by evaporation.

Any rain that falls to the ground leaves a net excess of heat in the atmosphere at cloud level. This heat may be of great magnitude. For example, ¼″ of rain liberates in the atmosphere as much heat as that received from sunlight in temperate latitudes during a single day. Thus if it is possible, by seeding clouds, to produce rain over large areas where it would not occur of its own accord, the heat generated should have a marked effect on the circulation of the atmosphere over areas even greater than that over which the rain fell.

It has long been an important meteorological problem to determine the mechanism by which the small droplets originally produced in clouds gather into the large drops needed for rain formation. About 1932, Bergeron proposed a theory which could account for more rapid growth of cloud droplets. When clouds rise so high that the temperature falls below freezing, the water droplets, instead of freezing, normally become supercooled, unless sublimation or freezing nuclei are present which initiate the phase change from water to ice. If such particles are absent or present in only small numbers, a cloud may remain supercooled, even down to −39°C.

When nuclei are present, the difference of vapor pressure between ice and supercooled water causes the ice crystals to grow and the droplets to evaporate. With relatively few nuclei, the snow crystals grow to relatively large size in a few minutes, and by coalescing, and, at lower altitudes, by gathering cloud droplets and finally melting, they may lead to heavy rain, where, without nuclei, there would have been none. Findeisen's observations supporting Bergeron's theories indicated that if freezing nuclei or sublimation nuclei could be introduced into clouds, it might be possible to control rainfall. He did not indicate, however, how such nuclei could be obtained.

In July, 1946, Vincent J. Schaefer found that even minute portions of a supercooled cloud give enormous concentrations (10^{12} per cm^3) of nuclei if they are only momentarily cooled to −39°C.

Dr. Schaefer, by breathing into a cold box containing air at a temperature of −20°C, produced a cloud of supercooled droplets. When a minute particle of dry ice, weighing only a few micrograms, is allowed to fall in this cloud, it leaves a track of growing ice crystals which, within a few seconds, become glistening snow crystals.

Calculations made in 1946 suggested that the critical temperature of spontaneous nucleation in air, supersaturated with respect to ice, is the result of surface tension that causes the initial nuclei to have internal pressures above 2000 atmospheres so that the first ice that forms is a single unit cell (8 molecules) of the high pressure form of ice (Ice II). When this particle grows to a size of two unit cells, the internal pressure falls sufficiently so that it changes into ordinary ice (Ice I). Because the original nuclei must always be of a definite size, there is a loss of a degree of freedom in the normal relation that governs the formation of liquid particles from a vapor phase, according to which the temperature of spontaneous formation should depend enormously on the vapor pressure.

In November, 1946, Schaefer, by dropping about three pounds of crushed dry ice per mile of flight into a lenticular supercooled cloud at an altitude of 14,000 feet, made the cloud change completely into ice crystals.

Also in 1946, Dr. B. Vonnegut discovered that fine particles of silver iodide produced by sublimation of silver iodide give nuclei on which supersaturated moisture can condense to form ice crystals at temperatures from −5°C to −10°C.

When a pop gun is made to explode in a supercooled cloud, he found that enormous numbers of ice crystals are formed, provided the initial pres-

* A paper, entitled "The Concept of Cultural Evolution in Modern Ethnology," by David Bidney, University of Indiana, Bloomington, Ind., was presented at a meeting of the Section of Anthropology on October 22, 1951, but the abstract had not been received prior to publication of this issue of TRANSACTIONS.

† This paper was presented as one of two papers in the Symposium on Cloud Seeding, held by the Section on October 23, 1951.

‡ General Electric Research Laboratory, Schenectady, N. Y.

sure in the gun exceeds that needed to give an adiabatic cooling to −39°C.

Schaefer has recently modified the experiment by using, instead of a pop gun, a small glass bulb containing air saturated with ice, this bulb being connected through a capillary tube to a source of air at a known pressure. If the bulb is broken by a blow, the sudden expansion of the air within a few microseconds causes the air to be cooled to the critical temperature. A count of the ice crystals produced in the cold box showed that there were 10^{12} nuclei per cm^3 in the little bulb when this was at −20°C. Thus 10^{18} effective nuclei were produced per gram of water vapor in the expanding air.

Experiments With the Seeding of Clouds by Dry Ice

A series of lantern slides illustrated the modifications in supercooled stratus clouds produced by dropping dry ice from a plane along a line at the rate of about one pound per mile of flight. Within a few seconds, a visible track is produced in the top of the cloud, which grows in width so that it frequently becomes three miles wide in 45 minutes. Within this lane, all the supercooled water is changed to ice crystals which proceed to fall. A cloud 1000 meters thick, even containing one gram per cubic meter of air, would give a precipitation of only about one millimeter, even if none of the moisture evaporated in falling from the cloud to the ground. These experiments prove conclusively, however, that enormous numbers of snowflakes can be produced by very small amounts of dry ice.

During the following summer, in 1947, and in subsequent years, a large number of experiments were made by dropping dry ice on large growing cumulus clouds. In practically all cases, profound modifications in the clouds were observed. Sometimes the clouds dissipate, but frequently in growing clouds heavy rain begins to fall within 15 to 20 minutes after seeding. Some of these rains have persisted for hours and have given several inches of rainfall. A large number of observations by radar have indicated that rain began at the place of seeding within a few minutes. It is, however, only rarely that one finds clouds suitable for the production of heavy rain by this method in a specific area where rain is desired.

Experiments in Honduras indicated that single pellets of dry ice shot by a gun from an airplane are sufficient to produce heavy precipitation from some growing cumulus clouds. Much depends on where the dry ice is introduced into the cloud. The best position is a point just above the freezing level so that the heat generated by the formation of the ice crystals sets up increased convective activity in the cloud. On the other hand, if ice crystals are produced near the top of the cloud, this part tends to float away, causing the dissipation of the cloud.

Widespread Effects of Silver Iodide Seedings

On October 14, 1948, burning charcoal impregnated with silver iodide was dropped from a Project Cirrus plane near Albuquerque, and an hour later three lots of approximately 25 pounds of dry ice were dropped on separate large growing cumulus clouds. These clouds developed into two large thunderstorms, and, during the next 18 hours, other storms developed from them, giving 590,000 acre feet of rain with a rainfall of more than 0.1″ (average 0.25″) over an area of 40,000 square miles, distributed about the point of seeding in accord with the known wind directions and velocities.

On July 21, 1949, a silver iodide ground generator was operated in New Mexico for a total of 13 hours, putting out 300 grams of silver iodide. Within 18 hours, 1,300,000 acre feet of rain fell with a rainfall of more than 0.1″ (average 0.32″) over an area of 68,000 square miles, distributed in space and time in accord with known wind velocities. An analysis of these two experiments was given in Project Cirrus Occasional Report No. 21, April 15, 1950, and a partial analysis in *Science* **111:** 35 (1950).

Since there were similar weather conditions on these two days, the second experiment may be considered a repetition of the first. Ferguson Hall, Science **113:** 189 (1951), and four members of the Landsberg Committee, G. Emmons, B. Haurwitz, G. P. Wadsworth, and H. C. Willett, Science **113:** 191 (1951), have discussed these Project Cirrus Reports and have concluded that that is no trustworthy evidence that the heavy rains of these days resulted from silver iodide seeding.

Much of the evidence that silver iodide did induce precipitation on these two days has been evaluated but not published. Instead of publishing the details which might provide adequate documentation, it seemed better to repeat these experiments. Early in December, 1949, a schedule of

regular weekly periodic seedings using about 1000 grams of silver iodide per week was started in New Mexico, and this has continued with a few modifications until two or three months ago.

Almost immediately, that is, during December, 1949 and January, 1950, it was noted that the rainfall in the Ohio River Basin began to show a definite weekly periodicity. A convenient way of measuring the degree of periodicity was to calculate the correlation coefficient CC between the rainfall on the successive days during a 28-day period, with the sine or the cosine of the time expressed as fractions of a week, the phase being taken to be 0 on Sundays.

Just before the start of the periodic seedings, the correlation coefficient CC(7) based on the seven average values for the successive days of the week of the 28-day period amounted to only 0.23, but in the next 28-day period, the value of CC(7) rose to 0.91.

TABLE 1 gives the average rainfall in inches per station day during 140 days at 20 stations designated as Group A in the Ohio Valley Basin, representative of an area of about 600,000 square miles. The successive rows correspond to five successive 28-day periods. It will be noted that the average rainfall on Monday was 0.272", whereas on Saturday it was only 0.064", a ratio of 4.3:1. The next to the last column gives CC(28), the periodic correlation coefficients for each 28-day period, and the last column gives the phases in the successive periods. Taking the 35 separate values for the 4-week averages given in the table, one gets CC(35) = 0.689 with a phase of 1.60 days. This result is statistically highly significant.

These periodicities in rainfall were evident at al-

TABLE 1

RAINFALL (INCHES PER STATION DAY) FOR GROUP A STATIONS FOR A 140-DAY PERIOD FROM DECEMBER 8, 1949 TO APRIL 29, 1950

Period	*Ave.*	*Sun.*	*Mon.*	*Tue.*	*Wed.*	*Thur.*	*Fri.*	*Sat.*	$CC(28)_5$	ϕ_5 Days
II	0.231	0.296	0.337	0.326	0.318	0.146	0.119	0.076	0.40	1.22
III	.210	.192	.257	.319	.190	.307	.181	.022	0.48	2.40
IV	.134	.089	.189	.290	.203	.116	.017	.038	0.56	2.43
V	.119	.206	.294	.032	.057	.049	.064	.126	0.26	0.11
VI	.104	.143	.280	.142	.034	.007	.037	.057	0.53	1.00
Ave.	0.160	.185	.272	.224	.158	.125	.084	.064		

$CC(35)_R = 0.689$ SF = 1700:1 ϕ = 1.60 days

TABLE 2

COMPARISON OF RAINS ON TUESDAY AND ON SATURDAY FOR 12-WEEK PERIOD—DECEMBER 13, 1949 TO MARCH 4, 1950

PERIODS II, III, IV

THESE DATA ARE TYPICAL OF CONDITIONS OVER ABOUT 1,000,000 SQ. MILES

	Buffalo		*Wilkes Barre*		*Philadelphia*	
Tuesday	*Tues.*	*Sat.*	*Tues.*	*Sat.*	*Tues.*	*Sat.*
Dec. 13	0.11	—	.75	—	0.38	—
20	.48	.09	—	—	—	—
27	.06	.01	.02	—	.29	—
Jan. 3	.60	.08	.14	—	.09	.04
10	.67	—	.47	—	.11	.05
17	—	.01	—	.01	.06	.02
24	.42	—	.14	.04	.01	.08
31	.35	—	.32	—	.65	—
Feb. 7	—	—	—	—	—	—
14	1.22	.13	.20	—	.64	—
21	0.21	—	.06	—	—	—
28	0.26	—	—	—	.04	—
Total	4.38	.32	2.10	.05	2.27	.19
Ratio	13.6		42.0		12.0	
Number of rains 0.10 or more	9:1		6:0		5:0	
Sig. factor	1200		90		70	

most any set of stations in the northeastern part of the United States. TABLE 2 gives the rainfall on successive Tuesdays and Saturdays during a 12-week period during the winter of 1949–1950 at Buffalo, Wilkes-Barre, and Philadelphia. This periodicity is almost the same as that found in the Ohio River Basin but with a one-day phase lag. The striking contrast between the total rains on Tuesdays and Saturdays runs parallel to the total number of days on which rains of 0.1″ or more occurred on Tuesdays and on Saturdays.

Maps have been prepared giving for 24 successive 28-day periods the distribution of correlation coefficients, CC(28), among 17 sub-divisions of the United States, these data being based on daily weather reports of 24-hour rainfall at 160 stations. During the first five 28-day periods, there were always several adjacent sub-divisions that showed high weekly periodicities in rainfall. After May, 1950, however, the periodicities became somewhat sporadic, although highly significant periodicities over large areas still occurred during more than half of the periods after July, 1950. Presumably the large amount of commercial silver iodide seeding in the western states (not done with a weekly periodicity) masks the effects of the periodic seedings in New Mexico. By a map, the areas were shown in which known seeding operations have been carried on in 1951. In 15 states west of the 95° W meridian (excluding Texas) about 550,000 square miles or 37 per cent of the total area of these states were under seeding contracts during 1951.

Maps for the months from December, 1949, through July, 1950, taken from the Monthly Weather Review illustrated the distribution of abnormally large rainfalls over the United States. The heavy rains nearly always occurred in a band extending from the southwestern to the northeastern states.

An analysis of the periodicity in the rainfall induced by periodic seeding was presented in a paper read October 12, 1950 before the National Academy of Sciences. The areas having a high weekly periodicity were generally the same as those showing the highest abnormalities in rainfall. Such heavy rains can only occur if the winds and the barometric pressures cause an adequate supply of moisture to flow from the Gulf of Mexico. The periodicities in the pressure differences between Corpus Christi and Jacksonville were studied. During the first 140 days after seeding began, there was a highly significant weekly periodicity indicating a periodic air flow from the Gulf.

The upper air temperatures, even up to the stratosphere, showed a high weekly periodicity over more than half of the United States. Nine stations representative of an area of 1,300,000 square miles gave 850 mb temperatures having CC(28) greater than 0.5. These data were published, in detail for Chicago and in summary for eight other stations, in the December issue of "The Bulletin of the American Meteorological Society," and a statistical analysis was given which proved that these periodicities were highly significant. Mr. William Lewis and Mr. E. Wahl, Bull. Amer. Met. Soc. **32:** 192–3 (1951), and Mr. Harry Wexler, Chem. Eng. News **29:** 3933 (1951), maintained, however, that these data on the periodicities in temperature were not truly significant and similar weekly periodicities have frequently occurred in the past.

TABLE 3

PERIODIC COMPONENT OF VARIANCE, APRIL 1950 AND 1949

	100W	90W	80W	Ave.
45N	63.6	71.6	47.1	60.7
	3.1	1.8	4.1	3.0
40N	70.4	82.2	49.2	67.3
	0.6	0.8	6.0	2.5
35N	29.7	18.3	27.7	25.3
	7.4	1.4	0.6	3.1
Ave.	55.6	57.4	41.3	51.1
	3.7	1.3	3.6	2.9

TABLE 4

RESIDUAL COMPONENT OF VARIANCE, APRIL 1950 AND 1949

	100W	90W	80W	Ave.
45N	59.5	37.4	48.1	49.2
	66.2	87.9	55.0	69.7
40N	37.6	33.0	67.9	46.1
	70.2	51.7	60.5	60.8
35N	26.1	56.6	53.5	45.4
	48.2	21.1	30.5	33.3
Ave.	42.0	42.3	56.5	46.9
	61.5	53.5	48.6	54.5

The degree of periodicity in upper air temperatures observed in 1950 during April, July, and November show a statistical significance of a much higher order of magnitude than those referred to by Lewis, Wahl, and Wexler. To illustrate this, an analysis has been made of the temperatures at the 700 mb level at nine stations in the United States at the intersections of the 80, 90, and 100° W meridians with the 35, 40, and 45° N parallels.

The values of CC(28) at these 9 points of intersection ranged from 0.50 to 0.85. The area represented is 1.5 million square miles.

Recently, we have extended this grid of regularly spaced stations to include the intersections of the 45° N parallel with the 70° W and 110° W meridian, these points giving CC values of 0.66 and 0.65 respectively. The 30° N, 80° W intersection just off Jacksonville, Florida also gave a correlation of 0.65. We thus have an area of two million square miles or ⅛ of the area of the United States in which CC(28) exceeds 0.50 with a mean value of CC(28) = 0.67.

We have also examined these periodicities at corresponding points for preceding and for following periods. The 28-day period in May showed low correlations. On the other hand, the two preceding periods gave highly significant values. Apparently, the high periodicity in the upper air temperatures started about January 25, 1950 and continued on until about May 1, 1950, covering an average area of about half of the United States.

For the nine points of intersection during a 28-day period in April, 1950, the total variance of the temperature was determined by taking the total sums of the squares of the deviations of these temperatures from their mean and dividing by 27, the number of degrees of freedom. The data obtained in this way are called the "total variance." By multiplying these values for each of the nine stations by the corresponding square of the correlation coefficient, CC(28), one obtains the "periodic component of the variance."

Exactly similar calculations were made for a 28-day period in April, 1949 when there was no periodic seeding. The results are given in TABLE 3. At each point, the upper figure is the "periodic component of variance" for the April, 1950 period, and the lower figure is the corresponding value for April, 1949. The average values for all these nine points show that the "periodic variance" in 1950 was 18 times as great as in 1949.

TABLE 4 gives the corresponding values of the "residual component of variance" obtained by subtracting the "periodic variance" from the "total variance." These data then indicate how all the other kinds of periodicities, beside the seven-day periodicity, compared with one another in the two years. It will be seen that there is only about a 10 per cent difference between the average variance of this type for 1950 and 1949.

It seems, therefore, that the temperature fluctuations in 1950 essentially differed from those in 1949 only in the superimposition of an extremely high seven-day periodicity.

Quite similar results have been obtained by detailed studies of the upper air temperatures in July, 1950 and November, 1950.

Seeding with Sodium Chloride

Observations in Puerto Rico in 1949 and in the Hawaiian Islands in 1951 have shown that the rainfall depends on relatively large particles of sea salt in the air, in accord with the publications of A. H. Woodcock and Mary Gifford. Calculations of the rate of growth of salt particles indicate that it should frequently be possible to induce heavy rainfall by introducing salt into the trade wind at the rate of about one ton per hour in the form of fine dust particles of about 25 microns in diameter. The heat generated by the condensation may liberate so much heat as to produce profound changes in the air flow and the synoptic conditions in neighboring areas.

AN EVALUATION OF THE TECHNIQUE OF CLOUD SEEDING TO DATE*

By FERGUSON HALL†

Rainmaking and other possibilities of weather control are stimulating topics, and the major attempt to increase rainfall in the West during the past season has been the subject of both interest and concern in many quarters. The last year has seen claims advanced of control of the major circulation of the atmosphere with a single silver iodide generator. Millions of dollars have been paid to professional "rainmakers" in the western half of the country in the hope of producing substantial changes in the rainfall regime. Such efforts have been supported not only by ranchers and farmers, but by large power companies, and even agencies of federal and local governments. Regulatory legislation has been enacted in several states, and numerous bills were introduced in Congress. Rainmaking efforts were credited with both the Kansas floods and the Arizona and New Mexico drouths. Many projects were instituted in foreign countries, some operated by rainmakers imported from the United States and others conducted by local scientists. Research in the basic mechanisms of precipitation and in the many aspects of cloud physics showed a marked increase, the feeling in many quarters being that only through a more complete understanding of natural processes could the possible effects of cloud seeding be determined.

Throughout the year the Weather Bureau has attempted to keep fully informed on all of the various aspects of the subject. It has conducted basic investigations of the physics of cloud and precipitation elements, and evaluations of several cloud seeding projects have been initiated. The suggestion by Project Cirrus that the weather over vast areas might be controlled with a single silver iodide generator seemed particularly interesting. The existence of such effects, if substantiated, would be of the greatest importance, not only in creating the possibility of substantial improvements in weather at small effort, but also in assessing the effects of the hundred or so odd generators which have been functioning in connection with commercial rainmaking projects. As a part of its research program, therefore, the Bureau has for the past year been reviewing the claims advanced by Cirrus in an attempt to establish by recourse to available data whether it is likely that large-scale effects were actually produced. This analysis is not complete at present. Because of the great interest in the matter, however, and in view of numerous statements by Cirrus, it has been thought desirable to present at this time a brief progress report containing some examples of the methods employed.

Seven-day Periodicities. Project Cirrus operated a silver iodide generator at Socorro, New Mexico, on a weekly periodic basis from the first part of December, 1949, to June, 1951. As understood, the purpose of this operation was to inject a weekly periodic component into the precipitation falling in the areas in which the silver iodide smoke was present. Study of rainfall data during the early periods of the experiment did indicate weekly periodicities in various sections of the country. It was noted, however, that similar periodicities were also present in other weather elements associated with the major circulation patterns of the atmosphere. Rainfall is known to be closely associated with these circulation patterns, and if periodicities were found in the circulation it would only be natural to expect them to be reflected in the rainfall. Project Cirrus thereupon enlarged its original hypothesis to include control of such quantities as upper-air temperatures, pressure-differences, tropopause heights, *etc.*

The Weather Bureau has attempted to determine first of all whether periodicities occurred during the time of seeding which would not be expected from normal weather sequences, and, secondly, whether any periodicities were geographically associated with the location of the seeding generator. The first step was necessary because it has been observed for many years that atmospheric motions often tend to fall into a periodic regime lasting for a month or more and having periods of around seven days.

A periodic component in a series of data can have a number of characteristics, such as amplitude, phase, duration, and correlation with the original data. The amplitude might be thought of as a measure of the importance of the compo-

* This paper was presented as the second of two in the Symposium on Cloud Seeding, held by the Section on October 23, 1951.
† United States Weather Bureau, Washington D. C.

nent; the phase and persistence of phase might show relationship to a driving mechanism, if any; the duration might relate both to the importance and predictability of the component; and the correlation might be thought of as a measure of the *relative* importance of the component as compared with the other variations present. In some cases, statistical theory provides significance tests for the reality of periodic components, but these tests are vitiated in time series data, such as weather observations, that usually show persistence and quasi-periodicities. For this reason, the familiar F-test was not used but a direct comparison was made between the periodic components in the meteorological data before and after seeding. The same components were used in the study of the geographical distribution of periodicities.

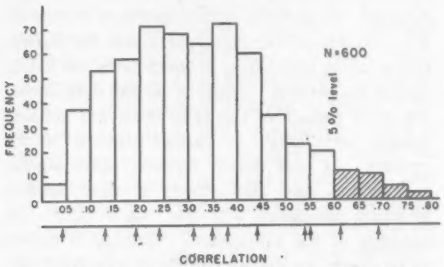

FIGURE 1. Histogram of correlation coefficients for 7-day component during 600 28-day periods. Pressure difference across northern Gulf of Mexico area (30°N 80°W minus 30°N 95°W).

One of the quantities in which Project Cirrus had found strong periodicities during the first months of seeding was the pressure difference across the northern edge of the Gulf of Mexico. The data, both during seeding, and back to 1899, was grouped into 28-day intervals, and the 7-day Fourier components of best fit were computed. FIGURE 1 shows a histogram of frequency distribution of correlation coefficients obtained from the 600 separate 28-day periods up to the beginning of seeding. Values for the first twelve 28-day periods of seeding are indicated by the arrows. It will be noted that several of the values are quite high, although not beyond the realm of experience. The first five seeding periods showed rather large coefficients and practically the same phase. This was taken as one of the most unusual events occurring during the seeding period. Examination of past data showed only one case as large (occurring in 1900), and, curiously, the phases of the two were almost identical. The effect, however, failed to reappear during the remainder of the seeding trials.

The next parameter investigated was the temperature at 700-mb. (approximately 10,000 ft.) over Omaha, in which Cirrus had found a large periodicity in April, 1950. Again a study was made of periodicities occurring in the past data back to 1935, when upper-air observations began. From the 200 28-day intervals prior to seeding, frequency distributions of correlation coefficients

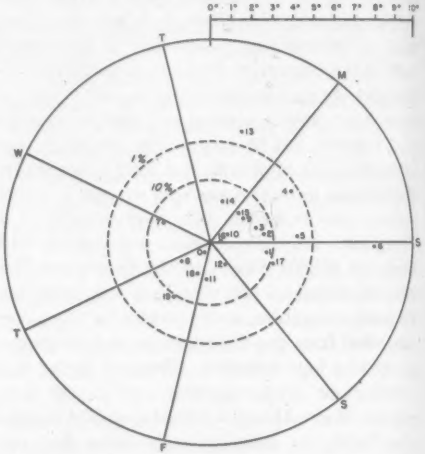

FIGURE 2. Harmonic dial showing amplitude (°C.) and phase (day of week) of 7-day component in 700-mb. Omaha temperature. 28-day periods beginning two months before regular seeding. Beginning dates of periods follow:

0—Oct. 16, '49	10—July 23
1—Nov. 13	11—Aug. 20
2—Dec. 11	12—Sept. 17
3—Jan. 8, '50	13—Oct. 15
4—Feb. 5	14—Nov. 12
5—Mar. 5	15—Dec. 10
6—Apr. 2	16—Jan. 7, '51
7—Apr. 30	17—Feb. 4
8—May 28	18—Mar. 4
9—June 25	19—Apr. 1

and amplitudes were prepared. Amplitudes and phases for each 28-day interval beginning October 16, 1949, two months prior to seeding, are presented on the harmonic dial shown in FIGURE 2. Circles labeled 10 per cent and 1 per cent indicate the relative frequency of occurrence of amplitudes of such magnitudes in the past data. It must be emphasized, however, that these relative frequencies are not too reliable for predicting the frequency to be expected during the seeding, because of sampling fluctuations and because of possible changes in the statistical population due to weather trends, *etc.* The different 28-day intervals are numbered, the seeding beginning with interval 2.

The large amplitude occurring in April, 1950, (point 6 in the diagram) appears quite unusual. Some of the other values are also somewhat higher than would be expected from the past records. It will be observed, however, that during much of the seeding experiment the amplitudes are quite normal. It can also be seen that no significant change accompanied the initiation of the regular seeding schedule (between points 1 and 2). The phase of the seeding was changed approximately 180° between periods 14 and 15, 16 and 17, and 18 and 19. No significant corresponding changes can be observed in the periodicities of the temperature. During period 16 the amplitude was so low, however, that it is doubtful if any periodicity existed.

The fact that high correlation coefficients, of the same order of magnitude as the highest during the seeding period, can be found from an inspection of past records, was illustrated by two articles appearing in the May, 1951, issue of the *Bulletin of the American Meteorological Society*. For example, Mr. William Lewis of the Weather Bureau describes the results of selecting three cases from a simple inspection of upper-air temperature data from 1938 to 1942. Perhaps the most striking of these cases is that at Bismarck, North Dakota, where a periodicity lasting 56 instead of 28 days was as significant as that for April, 1950, at Joliet, found by Dr. Langmuir of Project Cirrus. Periodicities were found in the surface temperatures at Boston by the Air Force Cambridge Research Center which were also comparable to the April, 1950, case.

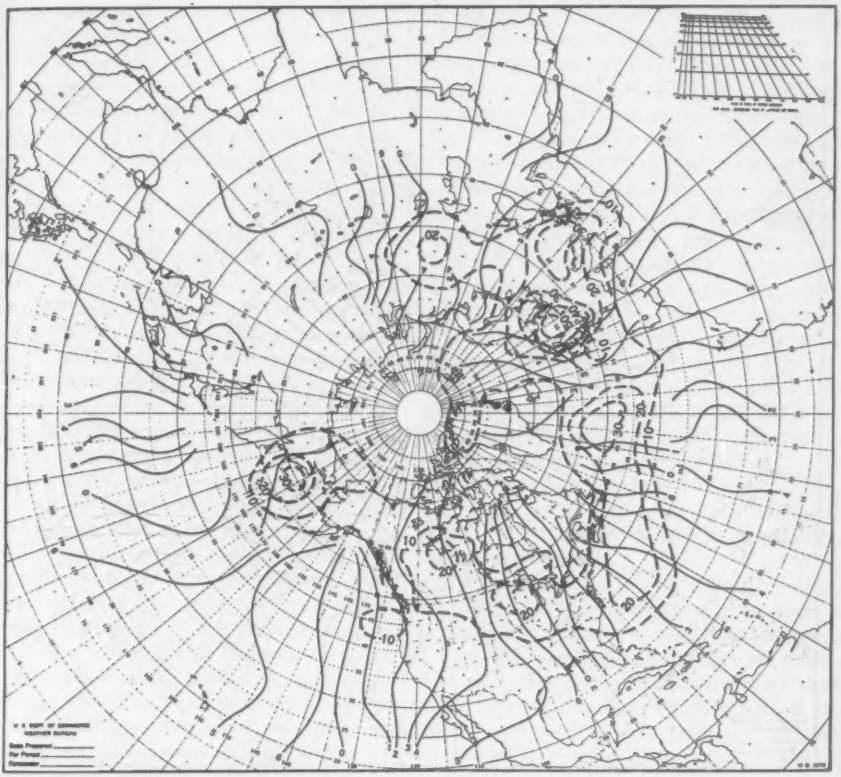

FIGURE 3. 7-day periodic component in height of 700-mb. surface. Amplitude factor—dashed lines. Day of maximum height—solid lines. April 2 to 29, 1950.

As mentioned, the Weather Bureau is also study-

ing the geographic distribution of 7-day periodicities over the entire northern hemisphere, beginning September 13, 1949, and continuing through the seeding period. This analysis also is not complete, but it is possible to present two charts of the series, one for the 28-day period beginning April 2, 1950, and the other for the period beginning January 7, 1951. The weather element in this case is the height of the 700-mb. surface. The charts (FIGURES 3 and 4) show centers of maximum amplitude of 7-day periodicity and lines of equal phase (day of week of maximum amplitude). It is striking that in both charts there are several "highs" of amplitude of periodicity throughout the northern hemisphere. This was also true prior to seeding, and during the other months of the experiment. It is also notable that in many cases the maximum amplitudes do not lie near the United States. Inspection of the available charts, furthermore, fails to disclose any significant concentration near the United States. Lines of constant phase appear to show regularity of spacing not only within the United States but at other points in the northern hemisphere. Similar distributions

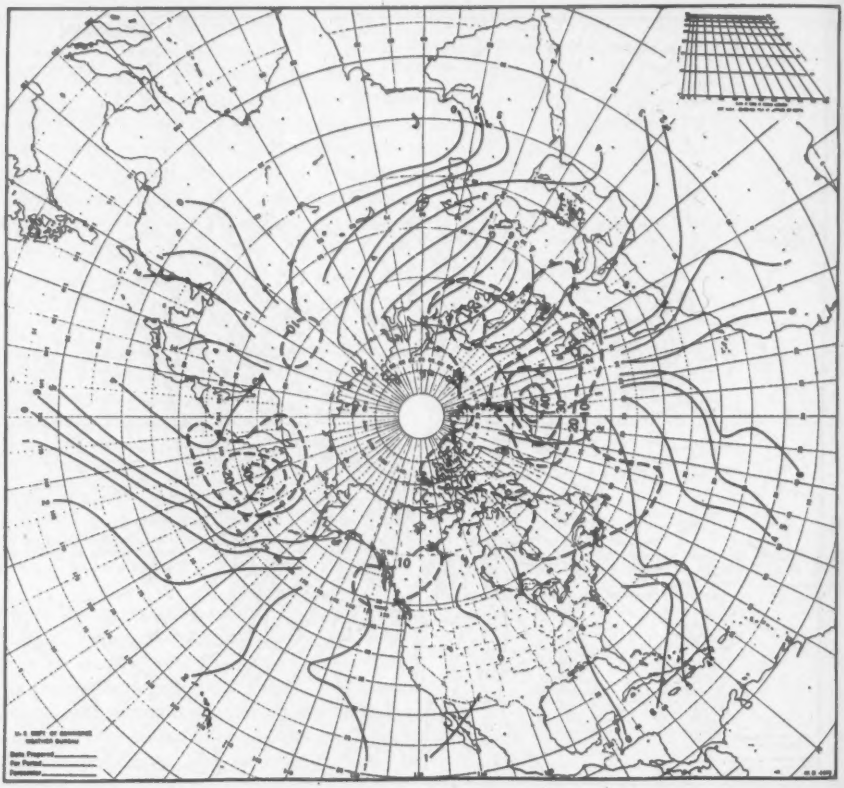

FIGURE 4. 7-day periodic component in height of 700-mb. surface. Amplitude factor—dashed lines. Day of maximum height—solid lines. January 7 to February 3, 1951.

of correlation coefficients will be prepared, and the analysis will be repeated for 700-mb. temperatures.

Questions of other than a purely statistical nature will undoubtedly arise in evaluating the probable effects of the project. It has been found by some investigators, for instance, that silver iodide deteriorates rapidly when exposed to sunlight. The rate of diffusion and trajectory of drift of silver iodide remain somewhat uncertain. The lack of any apparent physical connection between

the release of silver iodide and the upper-air temperatures, for instance, at great distances, raises other problems. Furthermore, the absence of any statement in advance of the project as to just what results would be looked for makes subsequent evaluation less rigorous.

General Aspects of Cloud Seeding. Turning now from the matter of periodicities, it will be interesting to review some of the other aspects of cloud seeding and rainmaking which have developed during the last year or so. As mentioned earlier, a considerable effort is being devoted to fundamental research into cloud physics and the mechanism of precipitation. A more complete understanding of these matters might eventually disclose any weaknesses in the natural processes that could be exploited to advantage, and would at the same time afford a basis for quantitative estimates of the effectiveness of human intervention. At present, however, cloud physics is really only in its infancy, thus making it almost impossible to answer questions regarding cloud seeding in the laboratory or with the slide rule.

Cloud seeding with dry ice or with silver iodide is, of course, based on the theory that raindrops and snowflakes begin their lives as tiny ice particles embedded in a cloud of supercooled cloud droplets, and that they grow to appreciable size at the expense of the liquid water in the cloud. Subsequent growth then results from collisions, both with each other and with cloud droplets. Recently a number of prominent meteorologists have discounted the need for ice particles, particularly in shower-type clouds, relying solely on the collision process. Their theory, however, requires the presence of a certain number of rather large cloud drops to initiate the process. If we assume for the present that the ice crystal theory is correct in our latitudes, we still have little information as to the natural concentration of ice particles in normal clouds. Cloud seeding assumes blithely that in all cases there are deficiencies in such crystals, and sets out to increase them in great numbers. Since most clouds of any considerable thickness (and which therefore contain substantial amounts of water) do produce rain or snow naturally, it would seem likely that large numbers of ice crystals are furnished in such cases by natural causes. Whether the concentration provided by nature is substantially optimum, as regards subsequent precipitation, is not known. Investigators believe they have noticed variations of the order of one million times in the concentration of ice producing nuclei in the air. It has not thus far been possible to detect any changes in the behavior of rain-bearing clouds of this order of magnitude. Curiously, there is even a considerable body of evidence supporting the theory that precipitating clouds contain too many rather than too few ice particles.

As a result of the apparent hopelessness of predicting cloud seeding results from purely physical principles, many field tests with dry ice have been conducted in different parts of the world. Possibly because of the publicity which attended the first experiments, most of the field tests were conducted on the supposition that the effects would be quite obvious, and that formal statistical design would not be necessary. It has turned out, however, that although the conversion of some supercooled cloud masses into ice crystals by airplane seeding falls into this "obvious" category, some of the more useful aspects of cloud seeding, such as producing large holes in cloud decks or laying down substantial rainfall on the ground, in any regular, predictable fashion, have not been definitely established. Other projects were conducted for the stated purpose of experimentation, and it was felt that an orderly procedure might unduly restrict the work. The only objection to this approach was that the experimenters often held up their rather isolated tests as almost final proof of the results of seeding to be expected generally throughout the world.

There still has been no systematic study of the possibility of creating large openings in layers of clouds. Even here it is probable that the factors involved are quite complex and that the process may work under certain conditions and not at all under different situations. With regard to the initiation or production of precipitation with dry ice, it seems fairly well established that seeding will initiate the process in certain non-raining clouds. The difficulty arises, as mentioned before, that clouds which are certain not to rain naturally usually contain insignificant amounts of moisture. If the larger clouds are taken for experiment, it is found that they are quite often precipitating naturally, or are about ready to precipitate. Here the experimenter is hard put to decide whether any rain which falls is natural or can be credited to the seeding operation. Tests with silver iodide ground generators are even more difficult, since we have no exact knowledge of the rate at which the smoke diffuses into the upper air or as to the drift of the substance downwind from the generator. Thus

we hardly know where to look for any results. Possibly as a consequence, we know of no scientificially designed studies of the effect of silver iodide upon precipitation.

It was not long after the announcement of the first seeding of clouds that the field was entered by professional "rainmakers." Such operators naturally assumed that the process would work, and consequently did not feel compelled to adopt orderly statistical procedures, if indeed such design is possible. Only rather crude evaluations of such operations can be made, and they may inquire only into the question of whether a particular rainmaker's operations produced a detectable effect on precipitation. Because of uncertainties as to the actual concentration of silver iodide in the atmosphere, virtually nothing can be learned of the possible or optimum effects which might be produced. A number of the rainmakers have offered their own evaluations of their operations, most of them tending to indicate positive results. In most cases, however, methods of analysis are not chosen in advance, nor in many cases has there been an attempt to determine the statistical significance of the results produced. Quite often it appears obvious that the variations noticed were well within the natural variations to be expected from natural causes. Independent evaluations of rainmaking projects in Colorado and Oregon have been made by the Colorado Agricultural and Mechanical College and by Oregon State College in cooperation with the Soil Conservation Service. Neither found evidence of significant effects.

Considering the broad aspects of adequate field tests of such an elusive agent as silver iodide smoke, it would appear almost necessary that instruments be developed to measure not only the concentration in the target areas, but such other factors as the natural ice nuclei content of the air and the ice crystal content of clouds, in cases both where precipitation is falling and those in which it is not. If wide variations in natural nuclei are present, as has been proposed, then a simple correlation between nuclei counts and the behavior of clouds in the vicinity should throw considerable light on the importance of nuclei in cloud physics. Addition of artificial nuclei would serve to extend the range of concentration, and thus permit studies of the effects of the higher values. At present, however, instrumentation is totally inadequate to permit these investigations. The sooner we can measure these important factors, the sooner the mysteries of precipitation processes, natural and artificial, can be solved.

In conclusion, it is the opinion of the Weather Bureau that in spite of the rather discouraging results of most of the field tests, it is likely that cloud seeding has some effect on precipitation. Our impression is that the effects must be quite modest, since it is so difficult to detect them. Whether their magnitude is purely nominal or whether they would be of economic consequence in certain areas, remains undetermined. Whether seeding may be useful only in special weather conditions is another factor that will eventually have to be considered. It is our feeling at the moment that the best chance for progress in answering these questions lies in advancing our knowledge of the mechanism of natural precipitation.

DIVISION OF MYCOLOGY

THE ISOLATION FROM SOIL OF FUNGI WHICH CAUSE DISEASE IN MAN*

By CHESTER W. EMMONS†

The hazards presented by pathogenic bacteria which reach the soil, and the ultimate fate of such bacteria, attracted the speculations and investigations of early bacteriologists. With few exceptions, however, the occurrence in soil of fungi which cause human disease has received relatively little study although their presence in soil has sometimes been assumed. On the few occasions when fungi causing human disease have been actually isolated from soil or plants, the significance of these observations has not been properly related to the general problem of sources of infection in the mycoses. This is surprising when one reflects that the systemic mycoses are not contagious, that some non-human reservoir of infection must therefore be sought, and that there is direct as well as circumstantial evidence that pathogenic fungi exist in a free state in man's environment. The idea that pathogenic fungi are present in soil may be implicit in some of the concepts of medical mycology, but the importance of the soil as a reservoir of the fungi causing systemic mycoses needs to be more clearly stated and emphasized.

The term soil is used in a broad sense to include a complex mixture of organic debris such as decaying plant material, humus, the excreta and keratinaceous and proteinaceous remains of insects, birds and animals, and the vast and varied microflora and microfauna of soil. The growth of pure cultures of pathogenic fungi in the laboratory on culture media prepared from plant products indicates that fungi which are physiologically adapted to parasitism of man are not dependent upon a high protein medium for growth under these favorable conditions. Some pathogens can undoubtedly grow in nature without an unusual concentration of proteins of animal origin. Gordon and Hagan[17] isolated pathogenic actinomycetes apparently identical with *Nocardia asteroides* from soil by utilizing paraffin as a selective medium.

Furthermore, it is easy to demonstrate that some pathogenic fungi will grow in the laboratory on sterilized soil if suitable conditions of moisture and temperature are met. I have grown *Trichophyton mentagrophytes*, *Cryptococcus neoformans*, *Blastomyces dermatitidis*, *Coccidioides immitis*, *Histoplasma capsulatum*, *Sporotrichum schenckii*, *Allescheria boydii*, *Phialophora pedrosoi*, and *P. verrucosa* on ordinary unenriched garden soil, sterilized in the autoclave at 15 lbs. pressure for 20 minutes, and incubated at 30°C. Further studies will be required to determine the optimum conditions under which pathogens are able to compete with saprophytes successfully in soil under natural conditions. It may well be, however, that the excreta and remains of animals, insects and microscopic organisms supply a preferential medium in which pathogens are able to meet and survive the competition of more rapidly growing saprophytic fungi.

Evidence for a free saprophytic existence of pathogenic fungi includes the clinical observations that the systemic mycoses are neither transmitted from person to person nor ordinarily acquired directly from an animal reservoir; that some types of mycoses develop after penetrating injuries; and that pulmonary mycoses may follow unusual exposure to dust. The noncontagious nature of systemic mycoses hardly needs further elaboration. Even when the patient is excreting the organism in large numbers in sputum, pus or feces, and although this contaminated excreta is experimentally infectious for animals, it is not effective in transmitting the disease through ordinary contacts. Family epidemics are almost unknown and, in the rare instances when direct transmission is suspected, there may have been a common exposure, some unusually close exposure, or some accidental surgical or laboratory contact. Exceptions occur in the case of the superficial dermatophytoses which are acquired directly or indirectly from other persons or from animals, and in moniliasis which probably is transmitted commonly from mother to infant.

Circumstantial evidence for the saprophytic existence of pathogens of man is strong in the case of the mycetomas because of the many cases in which lesions develop on the feet of agricultural laborers working barefoot in the fields. Many patients give a history of a puncture wound which

* This paper, illustrated with lantern slides, was presented at a meeting of the Section on October 26, 1951.

† Federal Security Agency, Public Health Service, National Institutes of Health, National Microbiological Institute, Bethesda, Md.

preceded development of the lesion. Similar exposures have been recognized in chromoblastomycosis.[4] Sporotrichosis has been associated in specific instances with presumptive implantation of spores by thorns of barberry or rose, and courts have recognized an employment-connected disability and awarded compensation for costs of medical care.[15] A remarkable and extensive outbreak of sporotrichosis was reported in workers in gold mines in South Africa and it was shown that the infection was related to exposure in certain mines and in some instances followed trauma.[3]

In the case of primary respiratory infections, it has been observed that coccidioidomycosis in endemic areas follows known exposure to dust storms or dust raised in agricultural occupations[22] and an occupational exposure in many cases of pulmonary aspergillosis has been noted.[21]

Several of the mycoses are common to man and animals. *Sporotrichum schenckii* causes sporotrichosis in the horse and dog.[19] Aspergillosis occurs frequently in birds.[21] Coccidioides causes disease in the dog and rodents[7] and induces a limited infection in cattle and sheep.[24] At the National Institutes of Health, we have found naturally acquired histoplasmosis, proved by isolation of the fungus, in the house mouse, brown rat, roof rat, spotted skunk,[13, 14] cat, striped skunk, opossum, and fox.[9, 10] Direct transmission from animal to man occurs rarely, if at all, in systemic mycoses, and it is probable that animals are infected from the same environmental source as man. One may speculate, from a knowledge of the nature of the disease in these animals and of the developmental cycle of the fungi, that there probably is no direct contagion from animal to animal, but rather a contamination of soil with an intervening saprophytic phase.

The immediate reversion of a pathogenic fungus to its saprophytic growth phase, when it passes from the animal body to an artificial culture medium, is a most familiar and predictable laboratory phenomenon. It is readily shown in the laboratory that the conidia subsequently developed are more resistant to deleterious environmental influences than the more delicate cells of the parasitic phase. Moreover, they may be produced in enormous numbers. It is easy to suppose, therefore, that the conidia are more efficient elements for dissemination of the fungus in nature. It can be shown experimentally that they are infectious for the animal and, indeed, because of their greater resistance, they may be more effective infectious agents than their parasitic counterparts.

More direct and conclusive evidence of the occurrence of pathogenic fungi in soil is furnished by their actual isolation from this medium. Without doubt, *Aspergillus fumigatus* has been isolated more frequently from soil than any other fungus causing disease in man. It has long been known as a common soil fungus[25] and the relative infrequency of pulmonary aspergillosis in man may be due to immunological factors, since it can hardly be ascribed to lack of exposure. *Sporotrichum schenckii* was isolated from plants by Beurmann and Gougerot in 1908.[2] A more recent isolation of many strains from the timbers and ground waters of deep shaft gold mines in South Africa[3] has already been mentioned. I have isolated this fungus from sphagnum moss associated with cases of sporotrichosis in florists,[16] and from two samples of soil collected on Virginia farms.[10, 12] Meyer[19] suggested that Sporotrichum growing in soil is the probable source of infection in human and animal infections and Mackinnon[18] correlated the seasonal occurrence of sporotrichosis with climatic conditions which he believed favored saprophytic development of the fungus.

Although isolation from soil of the principal species of fungus causing chromoblastomycosis has not been conclusively proved, Conant[6] showed that the second most important species, *Phialophora verrucosa*, is identical with *Cadophora americana*, isolated from wood. The isolation from soil of strains of *Nocardia asteroides*[17] was mentioned earlier. One wonders how often pathogenic strains of this and other actinomycetes pass unrecognized and are discarded in the vast programs of antibiotic screening now being conducted throughout the world.

The epidemiologic evidence for the presence of *Coccidioides immitis* in soil has been supported by actual isolation in three independent studies.[23, 6, 7] The conditions which limit the endemicity of this rapidly growing and non-fastidious fungus to desert areas of North and South America and Mexico have not been determined. The frequent occurrence of pulmonary coccidioidomycosis in certain species of desert-dwelling rodents suggested to the writer that these animals may play an essential role in the geographic distribution of the fungus.[7]

Although the present discussion is concerned with the fungi causing systemic disease it might be noted in passing that dermatophytes have been

isolated from debris in stables[20] and that *Microsporum gypseum* has been isolated from soil not obviously contaminated by animals, by the technique of "baiting," in which strips of wool cloth buried in soil provide a selective culture medium for wool-destroying fungi.[26]

Epidemiologic observations suggesting that fungi which cause human disease may be present in soil are, therefore, well substantiated by the actual isolation of pathogens from this medium.

The presence of pathogenic fungi in soil has been largely overlooked because the usual methods of determining soil flora have not been efficient in isolating them. For the most part, the pathogens grow slowly and are outnumbered, as well as outgrown, by saprophytes, so that the chances of isolating them directly, by dilution methods, are remote. The method of isolation which the writer has used since 1941 apparently had not previously been used and described in any systematic attempt to isolate pathogens from soil. It depends upon the simple principle that, when a suspension of soil containing a mixed bacterial and fungal flora is introduced into the peritoneal cavity of the guinea pig or white mouse, the saprophytic fungi and bacteria present, with few exceptions, are destroyed by the animal's defense mechanisms within a matter of three or four weeks, while pathogenic fungi survive, and, in some cases, are able to proliferate in the tissues. This method combines, in one operation, a screening technique by which pathogens can be isolated from most saprophytes, and a test, within limits, of the pathogenicity of an isolate. The procedure has been described in earlier papers.[8, 10] Ajello and Zeidberg[1] have recently used a modification in which they mix the soil suspension with mucin before injection of the mouse. This results in greatly increased mortality of the experimental animals and they have, therefore, administered large daily doses of penicillin and streptomycin to the mice after injection of the soil. They believe this modification is more efficient in the isolation of pathogens. It will be shown in a later paragraph, however, that the method, without recourse to mucin, is effective in isolating not only pathogens but also certain types of saprophytes which appear to have some potential pathogenic capacities. It is not necessary to the effectiveness of the method that the spores actually proliferate within the animal body. If they merely survive, they can be recovered by culture.

The writer has previously reported the isolation of *Histoplasma capsulatum*[8] and *Cryptococcus neoformans*[11] from soil. Twenty-eight additional isolations of Histoplasma and three of *C. neoformans* have been made since those reports.

At the 7th International Botanical Congress, where much of the foregoing material was presented,[10] other isolations of fungi from soil were reported for the first time. One of these was a yeast-like fungus which has not yet been identified. Its isolation from 107 animals and 97 soil samples has been recorded. Its virulence for animals is low. Studies of its pathogenicity have not been completed.

The isolation of *Allescheria boydii* from a soil sample in 1948 was also reported at that meeting.[10] This was the first time this fungus had been reported from any source except a human infection. Ajello and Zeidberg have recently reported the isolation of *A. boydii* from soil[1] and the writer has made a second recent isolation from soil.[12]

Some of the saprophytic fungi isolated from soil by this method are of considerable interest because they are capable of surviving several weeks in the peritoneal cavity of the mouse, although they do not produce progressive lesions. Species of Rhodotorula, Beauveria and Isaria fall within this category. The ability of Beauveria and Isaria to survive in the animal body may be related to their parasitism of insects. One species, *B. brumpti*, has been described from a human lesion. *Aspergillus clavatus*, in our studies, was isolated 12 times from soil and has been isolated many times from the lungs of rats. There is some indication of slight pathogenicity but studies have not been completed. Notable among saprophytes we isolated are *Microascus trigonosporus*, *M. intermedius* and *Microascus sp.*, which have been obtained from 82 soil samples by this technique. These fungi have long been known to occur in soil but the methods used have resulted in a surprisingly large number of isolations.

Summary. Greater attention should be given to the occurrence in soil of fungi causing human disease. Epidemiologic evidence suggesting that the soil is an important reservoir of such fungi is strengthened by actual isolation of pathogens. *Histoplasma capsulatum*, *Cryptococcus neoformans*, *Allescheria boydii*, *Nocardia asteroides*, *Aspergillus fumigatus*, *Sporotrichum schenckii*, *Coccidioides immitis*, dermatophytes, and several other fungi showing some indication of potential pathogenicity have been isolated from soil.

Bibliography

1. AJELLO, L. & L. D. ZEIDBERG. 1951. Isolation of *Histoplasma capsulatum* and *Allescheria boydii* from soil. Sci. **113**: 662–663.
2. BEURMANN, M. & M. GOUGEROT. 1908. Découverte du Sporotrichum Beurmanni dans la nature. Bull. et Mém. Soc. Med. Hop. de Paris. 3e Ser. **26**: 733–738.
3. BROWN, REBECCA, *et al.* 1947. Sporotrichosis infection on mines of the Witwatersrand. A symposium. The Transvaal Chamber of Mines, Johannesburg.
4. CARRIÓN, A. L. & M. SILVA. 1947. Chromoblastomycosis and its etiologic fungi. Biology of Pathogenic Fungi. Chronica Botanica Co., Waltham, Mass.
5. CONANT, N. F. 1937. The occurrence of a human pathogenic fungus as a saprophyte in nature. Mycologia **5**: 597–598.
6. DAVIS, B. L., R. T. SMITH & C. E. SMITH. 1942. An epidemic of coccidioidal infection. J. Amer. Med. Assoc. **118**: 1182–1186.
7. EMMONS, C. W. 1942. Isolation of Coccidioides from soil and rodents. Pub. Health Rept. **57**: 109–111.
8. EMMONS, C. W. 1949. Isolation of *Histoplasma capsulatum* from soil. Pub. Health Rept. **64**: 892–896.
9. EMMONS, C. W. 1949. Histoplasmosis in animals. Trans. N. Y. Acad. Sci. **2**: 248–254.
10. EMMONS, C. W. 1950. The natural occurrence in animals and soil of fungi which cause disease in man. Trans. 7th Inter. Bot. Cong. (In press.)
11. EMMONS, C. W. Isolation of *Cryptococcus neoformans* from soil. Jour. Bact. (In press.)
12. EMMONS, C. W. Unpublished observations.
13. EMMONS, C. W., J. A. BELL, & B. J. OLSON. 1947. Naturally occurring histoplasmosis in *Mus musculus* and *Rattus norvegicus*. Pub. Health Rept. **62**: 1642–1646.
14. EMMONS, C. W., H. B. MORLAN & E. L. HILL. 1949. Histoplasmosis in rats and skunks in Georgia. Pub. Health Rept. **64**: 1423–1430.
15. FOERSTER, H. R. 1926. Sporotrichosis, an occupational dermatosis. J. Amer. Med. Assoc. **87**: 1605–1609.
16. GASTINEAU, F. M., *et al.* 1941. Sporotrichosis. Report of six cases among florists. J. Amer. Med. Assoc. **117**: 1074–1077.
17. GORDON, R. E. & W. A. HAGAN. 1936. A study of some acid-fast actinomycetes from soil with special reference to pathogenicity for animals. Jour. Inf. Dis. **59**: 200–206.
18. MACKINNON, J. E. 1948. Las condiciones meteorológicas causa determinante de la frecuencia de la esporotricosis. An. Insto. Hig. Montevideo. **2**: 50–68.
19. MEYER, K. F. 1915. The relation of animal to human sporotrichosis. J. Amer. Med. Assoc. **65**: 579–585.
20. MUENDE, I. & P. WEBB. 1937. Ringworm fungus growing as a saprophyte under natural conditions. Arch. Derm. & Syph. **36**: 987–990.
21. RÈNON, L. 1897. Etude sur l'aspergillose chez les animaux et chez l'homme. Paris.
22. SMITH, C. E., R. R. BEARD, E. G. WHITING & H. G. ROSENBERGER. 1946. Varieties of coccidioidal infection in relation to the epidemiology and control of the diseases. Amer. J. Pub. Health. **36**: 1394–1402.
23. STEWART, R. A. & K. F. MEYER. 1932. Isolation of *Coccidioides immitis* (Stiles) from soil. Proc. Soc. Exp. Biol. Med. **29**: 937–938.
24. STILES, G. W. & C. L. DAVIS. 1942. Coccidioidal granuloma. J. Amer. Med. Assoc. **119**: 765–769.
25. THOM, CHARLES & K. B. RAPER. 1945. A Manual of the Aspergilli. Williams and Wilkins, Baltimore, Md.
26. WHITE, W. L., G. R. MANDELS & R. G. H. SIU. 1950. Fungi in relation to the degradation of woolen fabrics. Mycologia. **42**: 199–223.

CONFERENCES HELD

SECTION OF BIOLOGY

"INFLUENCE OF HORMONES ON ENZYMES"

JUNE 5 AND 6, 1951

The Section of Biology held a Conference on "Influence of Hormones on Enzymes." Doctor Ralph I. Dorfman, The Worcester Foundation for Experimental Biology, Shrewsbury, Mass. and Doctor E. D. Goldsmith, New York University, College of Dentistry, New York, N. Y. were the Conference Chairmen in charge of the meeting.

The program consisted of the following papers:

Tuesday, June 5

Morning Session. "Influence of Hormones on Tissue Enzyme Concentrations." Chairman, Gregory Pincus, The Worcester Foundation for Experimental Biology, Shrewsbury, Mass.

"Recent Studies on the *In Vivo* and *In Vitro* Effect of Hormones on Enzymes," C. D. Kochakian, Oklahoma Medical Research Institute and Hospital, Oklahoma City, Okla.

"β-Glucuronidase and the Action of Steroid Hormones," W. H. Fishman, Tufts College Medical School, Cancer Research and Control Unit, Boston, Mass.

"The Steroidal Hormones and Tissue Glucuronidase and Esterase," S. L. Cohen, University of Minnesota, Minneapolis, Minn.

"The Influence of Adrenalectomy and Cortisone Treatment on Enzymatic Reactions in Rat Tissues," W. W. Umbreit, Merck Institute for Therapeutic Research, Rahway, N. J.

Afternoon Session. "*In Vitro* Effects of Hormone-Enzyme Rates." Chairman, W. C. Stadie, University of Pennsylvania, Philadelphia, Pa.

"Influence of Steroids on Cerebral Metabolism," G. S. Gordan, R. C. Bentinck, and E. Eisenberg, University of California Hospital, San Francisco, Calif.

"Influence of Steroids on the d-Amino Acid Oxidase System," M. Hayano and R. I. Dorfman, The Worcester Foundation for Experimental Biology, Shrewsbury, Mass.

"Influence of Hormones on Enzymatic Activity," H. Jensen, Medical Department, Field Research Laboratory, Fort Knox, Ky.

"Effects of Steroids and Diethylstilbestrol on Dehydrogenase Systems," R. M. Hochster and J. H. Quastel, Research Institute, The Montreal General Hospital, Montreal, Canada.

"Metabolic Effects of Thyroxine *In Vitro*," H. A. Lardy and Gladys Feldott, University of Wisconsin, Madison, Wis.

Wednesday, June 6

Morning Session. "*In Vitro* Effects of Hormones—Carbohydrates and Fat Metabolism," Chairman, Abraham White, Chemical Specialties Company, Inc., New York, N. Y.

"The Effect of Insulin and Pituitary Hormones on Glucose Uptake in Muscle," M. E. Krahl and C. F. Cori, Washington University, St. Louis, Mo.

"The Combination of Insulin with Tissue," W. C. Stadie, University of Pennsylvania, Philadelphia, Pa.

"Influence of Hormones on the Disposition of Glucose in the Mammal," E. M. MacKay, The Scripps Metabolic Clinic, La Jolla, Calif.

"Effects of Epinephrine and Hyperglycemic Factor on Enzyme Systems in Liver," E. Sutherland, Washington University, St. Louis, Mo.

"The Effects of Cortisone and Growth Hormone on Ketogenesis by Surviving Liver Slices," J. Tepperman, State University of New York Medical Center, Syracuse, N. Y.

"CURARE AND ANTI-CURARE AGENTS"

JUNE 21 AND 22, 1951

The Section of Biology held a Conference on "Curare and Anti-Curare Agents." Doctor John A. Aeschlimann, Hoffman-La Roche, Inc., Nutley, N. J., was the Conference Chairman in charge of the meeting.

The program consisted of the following papers:

Thursday, June 21

Morning Session. Chairman, Klaus Unna, University of Illinois College of Medicine, Chicago, Ill.

"Recent Advances in the Pharmacology of Curare," A. R. McIntyre, University of Nebraska, College of Medicine, Omaha, Neb.

"The Pharmacology of Calabash Curare," David F. Marsh, West Virginia University, School of Medicine, Morgantown, W. Va.

Discussion of Dr. Marsh's paper led by W. D. M. Paton, London, England.

"The Isolation and Identification of Additional Physiologically Active Alkaloids in Extracts of *Chondodendron Tomentosum* Ruiz and Pavon," James D. Dutcher, Squibb Institute for Medical Research, New Brunswick, N. J.

"Curarization of Denervated Muscle," Leonard W. Jarcho, Barnett Berman, Carlos Eyzaguirre, and Joseph L. Lilienthal, The Johns Hopkins University and Hospital, Baltimore, Md.

Afternoon Session. Chairman, Klaus Unna.

"The Pharmacology of Decamethonium" W. D. M. Paton, Medical Research Council, National Institute for Medical Research, London, England.

"Synthetic Drugs Influencing Neuromuscular Activity," Edwin J. de Beer, Julio C. Castillo, Arthur P. Phillips, Rocco Fanelli, A. Lloyd Wnuck, and Stata Norton, The Wellcome Research Laboratories, Tuckahoe, N. Y.

"Pharmacology of Flaxedil," Walter F. Riker and W. C. Wescoe, Cornell University Medical College, New York, N. Y.

"A New Series of Synthetic Curare-Like Compounds," James O. Hoppe, Sterling-Winthrop Research Institute, Rensselaer, N. Y.

Friday, June 22

Morning Session. Chairman, Klaus Unna.

"Some Aspects of the Relationship Between Chemical Constitution and Curare-Like Activity," Daniel Bovet, Istituto Superiore Di Sanita, Rome, Italy.

"Pharmacology of Anti-Curare Agents," W. C. Wescoe and Walter F. Riker, Cornell University Medical College, New York, N. Y.

"Synthetic Curare-Like Compounds and Their Antagonists," L. O. Randall, Hoffman-La Roche, Inc., Nutley, N. J.

"Evaluation of Curarizing Drugs in Man. VI. Critique of Experiments on Unanesthetized Subjects," Klaus Unna and Edward W. Pelikan, University of Illinois College of Medicine, Chicago, Ill.

Afternoon Session. Chairman, Klaus Unna.

"The Evolution of the Use of Curare in Anesthesiology," Harold R. Griffith, McGill University, Montreal, Canada.

"Clinical Use of d-Tubocurarine," Arthur D. Console, Medical Division, E. R. Squibb and Sons, New York, N. Y.

"The Use of WIN 2747 in Anesthesiology," Francis F. Foldes, Mercy Hospital and The University of Pittsburgh School of Medicine, Pittsburgh, Pa.

"Clinical Evaluation of d-Tubocurarine and Tri-(diethylaminoethoxy)-1, 2, 3-Benzene (Flaxedil) and a series of Tri-methyl-phenyl Ammonium Compounds in Anesthetized Man," Joseph F. Artusio, Cornell University Medical College and The New York Hospital, New York, N. Y.

"WORLD POPULATION PROBLEMS AND BIRTH CONTROL"

OCTOBER 19 AND 20, 1951

The Section of Biology held a Conference on "World Population Problems and Birth Control." Doctor Carl G. Hartman, Ortho Research Foundation, Raritan, N. J. was the Conference Chairman in charge of the meeting.

The program consisted of the following papers:

Friday, October 19

Morning Session. "Population Control as a World Wide Problem." Chairman, Frank W. Notestein, Princeton University, Princeton, N. J.

"Population as a World Problem," Warren Thompson, Director, Scripps Institute of Population Research, Miami University, Oxford, Ohio.

"The Effect of Public Health Development upon Population Growth," Harold Dorn, National Institutes of Health, Washington, D. C.

"Social and Biological Factors in Human Fertility," Robert Cook, Editor of *Heredity*, Washington, D. C.

Afternoon Session. "Cultures, Mores, and Birth Control." Chairman, Halbert Dunn, Chief, National Office of Vital Statistics, National Institutes of Health, Washington, D. C.

"Control of Conception in Cross-Cultural Perspective," Clellan Ford, Yale University, New Haven, Conn.

"Present-Day International Trends in Family Planning," Abraham Stone, Director, Margaret Sanger Research Bureau, New York, N. Y.

"Medical and Medico-Social Indications for Contraception," Alan F. Guttmacher, Sinai Hospital and Johns Hopkins School of Medicine, Baltimore, Md.

Saturday, October 20

Morning Session. "Standards and Clinical Indications for Contraception." Chairman, Clarence J. Gamble, Milton, Mass.

"Biochemistry of the Female Genital Tract," W. T. Pommerenke and Mrs. M. A. Breckenridge, Rochester University School of Medicine and Dentistry, Rochester, N. Y.

"Biochemistry of the Male Genital Tract," John MacLeod, Cornell University School of Medicine, New York, N. Y.

"A Critical Study of Methods of Measuring Spermicidal Action," N. Millman, Ortho Research Foundation, Raritan, N. J.

Afternoon Session. "Standards and Clinical Indications for Contraception" (continued). Chairman, Carl G. Hartman.

"Simplified Birth Control Technique," (a) G. Wilson Hunter, Fargo Clinic, Fargo, N. D. and (b) William B. Stromme, Minneapolis, Minn.

"Recent Trends in the Study of Infertility," (a) "Ovaries and Fallopian Tubes—with Some Clinical Considerations of the Male," M. Edward Davis, Chicago Lying-In Hospital, University of Chicago, Chicago, Ill. (b) "Cervix and Uterus—Emotional Aspects of Infertility," Charles McLane, New York Hospital and Cornell University School of Medicine, New York, N. Y.

The Section of Biology provides conferences for active workers in the special fields of Biology.

Attendance is limited to those invited to participate in these conferences and to interested Members of the Academy.

EDITOR'S NOTE

Dr. D. B. Steinman, Life Member of the Academy, was awarded the Norman Medal by the American Society of Civil Engineers on October 24, 1951 for his paper entitled "Aerodynamic Theory of Bridge Oscillations." In awarding the medal, Waldo G. Bowman, chairman of the Society's committee on publications, said that the great merit of Dr. Steinman's paper lay in the fact that he had adapted proved aeronautical methods to the problem of bridge oscillation.

NEW MEMBERS

A. Elected June 15, 1950

SUSTAINING MEMBERSHIP

Andrews, George Clinton, M.D., Mycology. Professor of Clinical Dermatology, Columbia University, New York, N. Y.

Becart, August, M.D., Blood. Secretary, Paris Academy of Medicine, Paris, France.

Bingham, D. L. C., F.R.C.S., F.A.C.S., Surgery. Professor of Surgery, Queen's University, Kingston, Ontario, Canada.

De Blasio, Mary, M.S., Virology. Professional Assistant in Virology, E. R. Squibb & Sons, New Brunswick, N. J.

Fangemann, M. Gerard, M.E., Engineering Development. Manager, Spring Division, John Chatillon & Sons, New York, N. Y.

Glynn, John Gabriel, M.D., Psychology, Biology. Physician, Brooklyn, N. Y.

Grageroff, I., Ph.D., Chemistry, Explosives. Chief Chemist, Liberty Powder Co., Wabash River Division, Ind.

Jacobs, Albert Lionel, B.S., F.A.I.C., Pharmaceutical Chemistry. Patent Attorney, New York, N. Y.

Kessler, Sydney M., D.V.M., Veterinary Medicine. Brooklyn, N. Y.

Mack, Jr., Edward, Ph.D., Physical Chemistry. Chairman, Dept. of Chemistry, Ohio State University, Columbus, Ohio.

Mann, Jr., Charles H., B.A., M.D., Biology. Medical Director, Heyden Chemical Corp., New York, N. Y.

Miller, George, Ph.C., Pharmacological, Chemical. President, Strong Cobb & Co., Cleveland, Ohio.

Mufson, Isidor, M.D., Peripheral Circulation. Associate, Dept. of Medicine, Columbia University, New York, N. Y.

Parker, Milton E., B.S., Food Engineering. Director & Professor, Food Engineering, Illinois Institute of Technology, Chicago, Ill.

Provasoli, Luigi, Ph.D., Nutrition, Physiology of Protozoa. Chairman, Dept. of Biology, St. Francis College, Brooklyn, N. Y.

Richardson, George D., Biology, Histology. Director of Graphic Arts Div., Ortho Research Foundation, Raritan, N. J.

Spinola, Maurice W., Metallurgy. Consultant, New York, N. Y.

Trayford, Arthur, D.V.M., Veterinary Medicine. Huntington, N. Y.

Walborsky, Harry M., Ph.D., Organic Chemistry. Asst. Professor, Florida State University, Tallahassee, Fla.

Willett, Wendell M., M.D., Medicine, Dermatology. Assoc., Dermatology, The George Washington University, Washington, D. C.

Winn, Thomas J., B.S., Medicine, Chemistry. Manager, Antibiotic Division, Charles Pfizer & Co., Brooklyn, N. Y.

ACTIVE MEMBERSHIP

Bain, Alexander Francis, D.V.M., Bacteriology. Professor & Head, Dept. of Preventive Medicine, Ontario Veterinary College, Guelph, Canada.

Baker, Edward George, B.Sc., Electrical Conductivity of Aqueous Solutions. Graduate Student, Brown University, Providence, R. I.

Bandemer, Selma L., Ph.D., Physics, Chemistry. Assoc. Professor Research, Michigan State College, East Lansing, Mich.

Baum, S. James, M.D., Medicine. Senior Resident, Mt. Sinai Hospital, New York, N. Y.

Beardsley, Robert E., B.S., Microbiology. Student, Columbia University Dept. of Zoology, New York, N. Y.

Beathea, Rachel F., B.A., Biology. Instructor in Research, Dept. of Bacteriology, Michigan State College, Mich.

Bensted, John P. M., Biology. Medical Fellow, Dept. of Pathology, University of Minnesota, Minneapolis, Minn.

Blevins, Anne, Microbiology. Chief Technician, Dept. of Microbiology, N. Y. University, Bellevue Medical Center, New York, N. Y.

Bloom, Walter Lyon, M.D., Medicine. Asst. Professor, Biochemistry, Emory University, Ga.

Bovell, Carlton R., B.A., Microbiology. Instructor, Dept. of Biology, Brooklyn College, Brooklyn, N. Y.

Bowie, Walter C., D.V.M., Veterinary Physiology. Head, Dept. of Physiology, Tuskegee Institute, Ala.

Brayer, Franklin T., M.D., Cancer Research. Fellow in Dept. of Experimental Medicine, M.D. Anderson Hospital, Houston, Tex.

Brunell, Philip Alfred, B.S., Biology. Graduate Student, New York University, New York, N. Y.

Brunings, Karl J., Ph.D., Organic Chemistry, Biochemistry. Ass't. Director of Chemical Research, Chas. Pfizer & Co., Brooklyn, N. Y.

Campbell, Dan H., Ph.D., Immunochemistry. Professor of Immunochemistry, California Institute of Technology, Pasadena, Calif.

Carroll, Grayson, M.D., Pathology. Professor of Urology, St. Louis University, St. Louis, Mo.

Castaneda, M. Ruiz, M.D., Bacteriology. Director of Dept. of Medical Research, Hospital General, Mexico, D. F.

Chansky, Daniel, M.D., Psychology. Health Physician, Memorial Hospital, New York, N. Y.

Chu, George W.T.C., D.Sc., Public Health, Bacteriology. Professor, Dept. of Bacteriology, University of Hawaii, Honolulu, Territory of Hawaii.

Cohen, Irvin J., Medicine. Veterans Administration Hospital, New York, N. Y.

Coman, Dale Rex, M.D., Cancer, Pathology. Professor of Experimental Pathology, University of Pennsylvania, Philadelphia, Pa.

Crosby, Edwin L., M.D., Hospital Administration. Director, The Johns Hopkins Hospital, Baltimore, Md.

Cummings, Martin Marc, M.D., Bacteriology. Chief, Tuberculosis Research Laboratory, Lawson V. A. Hospital, Chamblee, Ga.

Curtis, Arthur Covel, M.D., Dermatology. Professor, Dept. of Dermatology, University of Michigan, Ann Arbor, Mich.

Daniels, Troy C., Ph.D., Pharmaceutical Chemistry. Dean, University of California, College of Pharmacy, San Francisco, Calif.

De Grandpre, Romeo, Ph.D., Cardiovascular Disease. Research Associate, University of Vermont, Burlington, Vt.

De La Balze, Felipe A., M.D., Metabolism. Professor of Medicine, University of Buenos Aires, Buenos Aires, Argentina.

Drent, John Henry, M.D., Pediatrics. Instructor, Dept. of Pathology, Tulane University, New Orleans, La.

Duffy, Jr., B. J., Radiobiology. Instructor in Medicine, Radiology Association, Atomic Energy Project, University of Rochester, Rochester, N. Y.

Elias, N. M., B.S., Chemical Engineering. Consultant, New York, N. Y.

Emele, Jane Frances, B.S., M.S., Pharmacology. Graduate Student, Dept. of Pharmacology, Yale University, New Haven, Conn.

Fall, Harry H., Ph.D., Chemistry. Research Chemist, The Upjohn Co., Kalamazoo, Mich.

Favour, Cutting B., M.D., Tuberculosis & Infectious Diseases. Assoc. in Medicine, Peter Bent Brigham Hospital, Boston, Mass.

Feirer, William A., M.D., Bacteriology. Vice-Pres., Scientific Affairs, E. R. Squibb & Sons, New York, N. Y.

Feitelberg, Sergei, M.D., Biophysics. Physicist, Mt. Sinai Hospital, New York, N. Y.

Finkel, Lucy, B.S., Medicine. Medical Librarian, The Hahnemann Med. College, Philadelphia, Pa.

Fisher, John C., D.SC., Physics, Metallurgy. Head, Physical Metallurgy Division, General Electric Research Laboratory, Schenectady, N. Y.

Fonda, Howard, Pharmaceutical Products. Senior Vice-Pres., Burroughs Wellcome & Co., Tuckahoe, N. Y.

Foshay, Lee, M.D., Infectious Diseases, Physiology. Professor of Bacteriology, University of Cincinnati, Cincinnati, Ohio.

Francis, David W., M.S., Poultry Diseases. Research Assistant, University of Delaware, Georgetown, Del.

Fresolone, Joseph Philip, B.S., Biology, Psychology. Newark, N. J.

Frick, Edwin Jacobs, D.V.M., Veterinary Medicine. Director of Clinics, Head, Dept. of Surgery & Medicine, Kansas State College, Manhattan, Kans.

Gardner, Elizabeth Bradbury, Ph.D., Physiology. Asst. Professor of Biology, Boston University, Boston, Mass.

Gershenfeld, Louis, D.Sc., Bacteriology. Head, Dept. of Bacteriology, Philadelphia College, Pharmacy & Science, Philadelphia, Pa.

Gezon, Horace Martin, M.D., Pediatrics, Bacteriology. Asst. Professor of Pediatrics, University of Chicago, Chicago, Ill.

Gibbs, Robert John, M.S., Protein Chemistry. Dept. of Chemistry, Fordham University, New York, N. Y.

Grace, Edwin J., M.D., Medicine. Director, Grace Clinic, Brooklyn, N. Y.

Grenfell, Thomas C., B.S., Pharmacy, Antibiotics. Asst. Director of Analytical Dept., Chas. Pfizer & Co., Brooklyn, N. Y.

Guruswami, M. N., B.A., Pharmacology. Dept. of Pharmacology, University of Michigan, Ann Arbor, Mich.

Hardy, Jr., Robert A., Ph.D., Organic Chemistry. Research Chemist, Calco Chemical Division, American Cyanamid Co., Bound Brook, N. J.

Hartline, Haldan Keffer, M.D., Physiology. Professor of Biophysics, Johns Hopkins University, Baltimore, Md.

Hausmann, Erich, D.Sc., Electrical Engineering, Physics. Head, Dept. of Physics, Brooklyn Polytechnic Institute, Brooklyn, N. Y.

Hedger, F. Howard, M.Sc. Chemistry. Director of Analytical Laboratories, Chas. Pfizer & Co., Brooklyn, N. Y.

Heller, John Herbert, M.D., Medical Physics. Chairman, Medical Physics Study Unit, Yale University, New Haven, Conn.

Hendricks, Franklin D., M.D., Antibiotics. Medical Officer, Food & Drug Administration, Washington, D. C.

Hochster, Rolf M., Ph.D., Enzymology. Research Fellow & Associate Biochemist, Montreal General Hospital, Montreal, Canada.

Holden, Margaret, Ph.D., Bacteriology. Associate, Bacteriology, Columbia University, New York, N. Y.

Horne, Stephen Francis, M.D., Dermatology, Syphilology. Private Practice, Rocky Mount, N. C.

Howard, Frank A., B.S., L.L.B., Physics, Chemistry. Patent Lawyer & Research Consultant, New York, N. Y.

Huddleson, I. Forest, D.V.M., Ph.D., Bacteriology, Biochemistry. Research Professor in Bacteriology, Michigan State College, East Lansing, Mich.

Huebner, Robert D., M.D., Peripheral Vascular Diseases. Research Fellow, Medicine, New York Hospital, New York, N. Y.

Hutchens, John C., Ph.D., General Physiology. Assoc. Professor, Dept. of Physiology, University of Chicago, Chicago, Ill.

Irwin, John S., B.S., Nuclear Energy. Consulting Engineer, Yonkers, N. Y.

Hudson, Imogene Moore, Ph.D., Zoology, Medicine. Medical Writer, E. R. Squibb & Sons, New York, N. Y.

Jaffe, Bernard, M.Sc., Biochemistry. Senior Biochemist, Philadelphia General Hospital, Philadelphia, Pa.

Jaques, William Everett, M.D., Pathologic Anatomy. Assistant Pathologist, Children's Medical Center, Boston, Mass.

Kabara, Jon J., Medical Research. Research Assistant, University of Miami, Coral Gables, Fla.

Kagan, B. M., M.D., Pediatric Research. Chairman, Dept. of Pediatrics, Michael Reese Hospital, Chicago, Ill.

Kajdi, Laslo, M.D., Pediatrics. Asst. Professor of Pediatrics, Johns Hopkins University, Medical School, Baltimore, Md.

Katz, Irmelle, Ph.D., Mycology. Research, Wallerstein Laboratories, New York, N. Y.

Kauffeld, Theodore J., M.E., Mechanics, Electrical & Civil Engineering. Consulting Engineer, President, Devenco Inc., New York, N. Y.

Kerr, Ralph W., Ph.D., Carbohydrates, Enzymes. Senior Chemist, Research Dept., Corn Products Refining Co., Argo, Ill.

Kinney, James R., D.V.M. Director & Chief Veterinary, N. Y. Women's League for Animals, New York, N. Y.

Kline, Irene T., Ph.D., Endocrinology. Research Assistant, Yale University, New Haven, Conn.

Klonymus, Rachel H., B.A., Zoology, Medicine. Graduate Assistant, Dept. of Zoology, Syracuse University, Syracuse, N. Y.

Kramer, Mort, D.V.M., Animal Physiology. Director of Animal Physiology, Institute of Applied Biology, Brooklyn, N. Y.

Kwong, Tin-Yu, M.D., Medical Science. Resident Physician, Hollywood Presbyterian Hospital, Hollywood, Calif.

Kun, Ernest, M.D., Enzymology. Asst. Professor of Medicine, Tulane University, New Orleans, La.

Lardy, Henry A., Ph.D., Enzymes, Metabolism. Professor of Biochemistry, University of Wisconsin, Madison, Wis.

Leloir, Luis F., M.D., Biochemistry. Director of Inst. de Biochemistry. Buenos Aires, Argentina.

Lepper, Mark, Experimental Medicine. Asst. Professor of Preventive Medicine, University of Illinois, Chicago, Ill.

Lewin, Cynthia, M.A., Psychology. Research Consultant, New York, N. Y.

Ling, Alfred Soy Chou, M.Sc., Physiology. Graduate Student, University of Illinois, Urbana, Ill.

Lyon, Braden M., D.V.M., Biology. Administrative Director, Lederle Labs., Division, American Cyanamid Co., Pearl River, N. Y.

Macdonald, Frances, B.S., Biology. Biometrician, New York Hospital, New York, N. Y.

Macdonald, Mary, B.A., Biology. Biometrician, Memorial Hospital, New York, N. Y.

Mann, James, M.D., Psychiatry. Director, Briggs Clinic, Boston State Hospital, Boston, Mass.

Masoro, Edward Joseph, Ph.D., Physiology. Asst. Professor of Physiology, Queens University, Kingston, Ontario, Canada.

Meglitsch, Paul A., Ph.D., Protozoology, Zoology. Assoc. Professor of Biology, Drake University, Des Moines, Iowa.

Meyers, Lewis S., B.Ch., Chemical Engineering. Chemical Engineer, Plant Manager, C. J. Osborn Co., Linden, N. J.

Nakamura, Kazuko, M.S., Pharmacology, Anthropology. Research Associate, Cedars of Lebanon Hospital, Los Angeles, Calif.

Nathanson, Sidney, D.V.M., Biology, Medicine. Veterinarian in Private Practice, Hollis, N. Y.

Payne, Howard Marshall, M.D., Anti-Microbial Drugs. Professor in Medicine, Howard University, Washington, D. C.

Perlstein, Dorothy, B.A., Biology. Medical Technician, Certified Blood Donor Service, Jamaica, N. Y.

Pierce, Cynthia H., Ph.D., Bacteriology. Assistant, Dept. of Pathology, Rockefeller Institute for Medical Research, New York, N. Y.

Portella, Oswaldo Balthazar, M.D., Medicine. World Health Organization, Washington, D. C.

Preston, Edward C., D.V.M., Psychology, Nutrition of Dogs. Preston Animal Hospital, Newton, N. J.

Riese, Hertha R. I., Child Psychiatry. Director, Educational Therapy Center, Richmond, Va.

Riggins, H. McLeod, M.D., Internal Medicine. Asst. Clinical Professor of Medicine, Columbia University, New York, N. Y.

Roberts, Charles S., D.V.M., Veterinary Pathology. Pathology, Alabama Polytechnic Institute, Auburn, Ala.

Rohweder, Claus A., Endocrinology. Asst. Professor Osteopathic Medicine, Kirksville College of Osteopathy & Surgery, Kirksville, Mo.

Roo, Jose Salvador, Biology, Psychology, Chemistry. Mexico, D.F., Mexico.

Rosenfelder, William J., Ph.D., Chemistry, Biochemistry. President, Meta Chemical Corp., Newark, N. J.

Russell, A. David, M.D., Pharmacology. Exec. & Director, Russed Pharmacal Corp., New York, N. Y.

Salvadori, Mario Giorgio, D.C.E., Civil Engineering.

Professor of Civil Engineering, Columbia University, New York, N. Y.

Scherr, George H., Ph.D., Microbiology. Asst. Professor, The Creighton University, Omaha, Neb.

Slavin, Howard B., M.D., Infectious Diseases. Assoc. Professor, University of Rochester, Rochester, N. Y.

Snyder, John Crayton, M.D., Microbiology. Professor of Microbiology, Harvard University, Boston, Mass.

Speirs, Robert Sisson, Ph.D., Endocrinology. Research Fellow, Roscoe B. Jackson Memorial Lab., Bar Harbor, Maine.

Spencer, Donald Clayton, Ph.D., Mathematics. Assoc. Professor, Princeton University, Princeton, N. J.

Stephenson, Kathryn Lyle, M.D., Tissue Transplantation. Plastic Surgeon, Santa Barbara Clinic, Santa Barbara, Calif.

Stewart, Gordon S., Ph.D., Endocrinology. Asst. Attending Biochemist, Presbyterian Hospital, Chicago, Ill.

Stone, William S., M.D., Ph.D., Preventive Medicine. Commandant, Army Medical Service, Graduate School, Army Medical Center, Washington, D. C.

Susinno, Anthony M., M.D., Internal Medicine. Assoc., Allergy Clinic, Englewood Hospital, N. J.

Sussman, Marcy Lee, M.D., Biology. Private Practice, Radiology, Phoenix, Ariz.

Svigals, Chester S., M.D., Internal Medicine. Private Practice, New York, N. Y.

Talalay, Paul, M.D., Surgery. Research Associate, Dept. of Surgery, University of Chicago, Chicago, Ill.

Thevathasan, Oliver I., M.A., Zoology. Graduate Student, New York University, New York, N. Y.

Turnbull, David, Ph.D., Physics, Chemistry. Head of Division of Chemical Metallurgy, General Electric Co., Schenectady, N. Y.

Viergiver, Ellenmae, Ph.D., Biochemistry. Chemist, Ayer Clinical Laboratory, Pennsylvania Hospital, Philadelphia, Pa.

Voyles, Carl M., M.D., Internal Medicine. Instructor in Medicine, Duke University, Durham, N. C.

Watkins, Jr., William Thurman, M.D., Dermatology. Instructor in Dermatology, Duke University, Durham, N. C.

Weedon, Frederick Renfroe, M.D., Biochemistry. Director, Municipal Lab., Jamestown, N. Y.

Wilensky, Nathan D., M.D., Medicine. Assoc. Visiting Physician, Kings County Hospital, Brooklyn, N. Y.

Wiley, Richard Haven, Ph.D., Organic Chemistry. Chairman, Dept. of Chemistry, University of Louisville, Louisville, Ky.

Wilks, Jr., Paul A., B.S., Optical Instruments. Asst. Director Sales & Research, Perkin Elmer Corp., Norwalk, Conn.

Winsten, Seymour, M.Sc., Microbiology. Technician, Merck Institute, Jersey City, N. J.

Winterscheid, Loren C., B.A., Bacteriology. Medical Research Fellow, National Tuberculosis Association, Philadelphia, Pa.

Woodward, Theodore E., D.Sc., Internal Medicine. Assoc. Professor of Medicine, University of Maryland, Baltimore, Md.

Wotiz, Herbert H., Ph.D., Organic Chemistry. Research Fellow, Dept. of Medicine, Boston University, Boston, Mass.

Wunderly, Charles, Ph.D., Protein Metabolism. Research Dept., Medizin University, Klinik, Zurich, Switzerland.

Zons, Frederick W., Ph.D., Rare Metals, Earths. Manager, Industrial Research & Trade Labs., New York, N. Y.

B. Elected July 13, 1951

SUSTAINING MEMBERSHIP

Buckman, Stanley Joseph, Ph.D., Industrial Microbiology. President, Buckman Laboratories Inc., Memphis, Tenn.

Fairless, Benjamin F., Engineering. President, United States Steel Corp., Pittsburgh, Pa.

Goll, Milton, B.A., Industrial Microbiology. Chief of Microbiological Labs., Nuodex Products Co., Elizabeth, N. J.

Heizer, Pauline, Ph.D., Chromosome Cytology. Asst. Professor of Zoology, University of Hawaii, Honolulu, Territory of Hawaii.

Kaletsky, Theodore, D.D.S., Oral Pathology. Dental Examiner, N.Y. State Dept. of Education, New York, N. Y.

Monier, Mary Mills, Ph.D., Biochemistry. Asst. Professor of Biochemistry, George Washington Medical School, Washington, D. C.

Schiff, Eugene, B.S., Biology, Pharmacy, Chemistry. Technical Director, Schiff Bio-Food Products, Jersey City, N. J.

Wince, Maurice G., M.D., Internal Medicine. University Physician, University of Akron, Akron, Ohio.

Yeager, Charles C., Ph.D., Industrial Microbiology. Microbiologist, Chicago, Ill.

ACTIVE MEMBERSHIP

Abramson, Arthur S., M.D., Physical Medicine. Chief, Physical Medicine Rehabilitation Service, Veterans Administration Hosp., New York, N. Y.

Berkowitz, Benjamin J., M.A., Chemistry. Doctoral Research Student, Columbia University, New York, N. Y.

Boines, George J., M.D., Medicine. Chief of Communicable Diseases in Wilmington General and St. Frances Hospitals, Wilmington, Del.

Burke, Grafton E., M.D., Cardiovascular Diseases. Instructor in Medicine, Cornell Medical School, New York, N. Y.

Caccese, Anthony, M.D., Internal Medicine. Private Practice, Brooklyn, N. Y.

Cantor, Abraham, Ph.D., Bacteriology. Asst. Professor of Bacteriology, Akron University, Akron, Ohio.

Carlo, Pierre Emmanuel, Ph.D., Pharmacology. Asst. Professor of Pharmacology, George Washington University, Washington, D. C.

Carsten, Mary E., Ph.D., Biochemistry. Fellow, Chemistry, Elmhurst, L.I., N. Y.

Cole, Berwin Abbey, Ph.D., Protozoology. Asst. Chief, Army Medical Service Graduate School, Washington, D. C.

Collins, Vincent J., M.D., Anesthesiology. Director of Anesthesiology, St. Vincent's Hospital, New York, N. Y.

Consolazio, William V., B.S., Biochemistry. Head, Biochemistry Branch, Office of Naval Research, Washington, D. C.

Daubert, B. F., Ph.D., Chemistry. Research Professor of Chemistry, University of Pittsburgh, Pittsburgh, Pa.

Davis, John H., M.D., Surgery. Associate in Research, Brooke Army Hospital, Fort Sam Houston, Tex.

De Goes, Paulo, M.D., Microbiology. Professor of Microbiology, University of Brazil, Rio de Janeiro, Brazil.

Drake, Miles E., Pediatrics. Research Dept. Member, Children's Hospital of Philadelphia, Philadelphia, Pa.

Durbin, Gerald T., B.A., M.A., Microbiology. Microbiologist, Research Laboratories, Wyeth Inc., Mason, Mich.

Eaton, William W., Ph.D., Engineering, Physics. Assoc. Director of Research, Olin Industries, Inc., New Haven, Conn.

Emma, Edwin, M.D., Anesthesiology. Assoc. Anesthetist, Beth Israel Hospital, New York, N. Y.

Engelberg, Hyman, M.D., B.A., Cardiology. Practising Physician, Los Angeles, Calif.

Fiske, G. Hastings, D.Sc., General Medical Research. Vice-President of Research Control, Eli Lilly & Co., Indianapolis, Ind.

Flaumenhaft, Irving, B.A., M.A., Protective Coatings. President & Technical Director, Lacquer & Chemical Corp., Brooklyn, N. Y.

Flon, Helen, B.A., Microbiology. Research Bacteriologist, National Foundation for Infantile Paralysis, Bronx Botanical Gardens, New York, N. Y.

Fox, Ernest L., M.D., Vascular Diseases. Research Fellow, Dept. of Medicine, Cornell University, New York, N. Y.

Fuerst, Robert, B.S., M.A., Microbiology. Research Scientist, M. D. Anderson Hospital for Cancer Research, Houston, Tex.

Garrard, Edward H., B.S.A., M.S.A., Agricultural Bacteriology. Professor & Head, Dept. of Bacteriology, Ontario Agricultural College, Guelph, Canada.

Glenn, Morton B., M.D., Internal Medicine. Asst. Resident in Medicine, Bellevue Hospital, New York, N. Y.

Goble, Guy J., Entomology. Bioassay Laboratories, Julius Hyman & Co., Denver, Col.

Goldsmith, Grace A., M.D., Nutrition & Metabolism. Professor of Medicine, Tulane University, New Orleans, La.

Gray, Grace W., Ph.D., Pharmacology. Graduate Student, & Research Assistant, Dept. of Pharmacology, University of Michigan, Ann Arbor, Mich.

Gray, Peter, Ph.D., Zoology. Head, Dept. of Biological Sciences, University of Pittsburgh, Pittsburgh, Pa.

Green, James D., M.D., Medicine. Private Practice, Birmingham, Mich.

Grimson, S. B., Color Research. Director, Color Research Corp., New York, N. Y.

Gumport, Stephen L., M.D., Surgery. Practice of Surgery, New York, N. Y.

Hagan, William A., D.V.M., Veterinary Pathology. Professor & Dean, N. Y. State Veterinary College, Cornell University, Ithaca, N. Y.

Hatch, Alden B., Ph.D., Biology, Antibiotics. Director, Fermentation & Development Division, Bristol Laboratories, Syracuse, N. Y.

Hechler-Wichelhausen, R. M., Rheumatic Diseases. Chief, Arthritis Research, Veterans Administration Hospital, Washington, D. C.

Heckerman, Raymond O., B.S., M.S., Embryology, Genetics. Instructor, Duquesne University, Pittsburgh, Pa.

Herman, Samuel E., D.V.M., Veterinary Science. Small Animal Practitioner, New York, N. Y.

Hershey, Solomon G., B.S., M.D., Anesthesiology. Director of Anesthesiology, Beth Israel Hospital, New York, N. Y.

Holoday, Duncan A., M.D., Pharmacology. Asst. Professor of Anesthesia, Columbia University, New York, N. Y.

Hollabaugh, Cleveland B., Ph.D. Cellulose Derivatives. Independent Patent Attorney, Garden City, L. I., N. Y.

Holle, Henry A., M.D., Medicine, Public Health. Regional Medical Director, U. S. Public Health Service, New York, N. Y.

Howard, Nathan Z., Private Practice, Great Neck, L. I., N. Y.

Hyman, Jr., Mark, B.A., M.S., Chemistry. President, Pilot Chemicals Inc., Waltham, Mass.

Katzin, Herbert, M.D., Ophthalmology. Director, Research Eye Bank for Sight Restoration, New York, N. Y.

Keltz, Alan, B.A., Biochemistry. Research Fellow, University of Southern Cal., Los Angeles, Calif.

Kleinholz, Lewis H., Ph.D., Biology, Professor of Biology, Reed College, Portland, Ore.

Kline, Albert P., Ph.D., Biology, Chemistry, Surgery. Assoc. Chem., N.E. Missouri State College, Kirksville, Mo.

Kopp, Moe, D.V.M., Veterinary Medicine. Private Practice, Port Chester, N. Y.

Kraus, Jr., Michael B., Electronic Engineering, Microbiology. Sales Field Engineer, Transmitter Equipment Mfr. Co., New York, N. Y.

Kreutzer, William A., M.S., Ph.D. Control of Soilborne Phytopathogens. Head Dept. of Plant Pathology, Shell Agriculture Lab., Modesto, Calif.

Little, George Watson, D.V.M., Biology, Physics & Chemistry. Private Practice, New York, N. Y.

Lu, Frank C., M.D., Pharmacology. Pharmacologist, Dept. of National Health & Welfare, Ottawa, Canada.

Mallory, G. Kenneth, M.D., Pathology. Director of Mallory Institute of Pathology, Boston City Hospital, Boston, Mass.

Mandel, Benjamin, Ph.D., Virology. Research Assistant in Microbiology, N. Y. University, New York, N. Y.

Markee, J. E., Ph.D., Muscle Function, Endocrinology. Professor & Chairman, Dept. of Anatomy, Duke University, Durham, N. C.

Mast, George W., M.D., Medical Research, Medical Director, Nepera Chemical Co., Yonkers, N. Y.

Merrill, A. P., M.D., Hospital Consultant, St. Barnabas Hospital, New York, N. Y.

Monroe, Russell R., M.D., Psychology. Asst. Professor Tulane University, New Orleans, La.

Morgan, Stanley L., B.S., Microbiology. Manager, Ben Venue Laboratories, Inc., Bedford, Ohio.

Muehlbauer, Michael, M.D., Biology. Brooklyn, N. Y.

Munsell, Hazel E., Ph.D., Nutrition. Director, Bromatological Laboratory, Instituto Nacional de Nutrician, Quito, Ecuador.

Nolan, Edward P., M.D., Medicine. Staff, Medical Center, University of New York, Syracuse, N. Y.

Orkin, Louis R., M.D., Anesthesiology. Asst. Professor of Anesthesiology, N. Y. University, New York, N. Y.

Ottolenghi, Mario L., Chemical Engineering. Technical Consultant, Director of Montecatini Inc., New York, N. Y.

Rechtschaffen, Joseph S., M.D., Internal Medicine. Metropolitan, Flower & Beth Israel Hospitals, New York, N. Y.

Reiss, Eric., M.D., Medicine. Assoc. Physician, Brooke Army Hospital, Fort Sam Houston, Tex.

Rosenberg, Lawson L., Ph.D., Chemistry. Asst.,

Dept. of Physical Chemistry, The Johns Hopkins University, Baltimore, Md.

Ross, Sidney, M.D., Clinical Investigation. Asst. Professor of Pediatrics, Georgetown University, Washington, D. C.

Sands, Abraham M., M.D., Opthalmalogy. Opthalmic Surgeon, N. Y. State University, Brooklyn, N. Y.

Schulman, Arnold, Physiology. Graduate Student, Yale University, New Haven, Conn.

Schwert, George W., Ph.D., Biochemistry. Asst. Professor of Biochemistry, Duke University, Durham, N. C.

Scudder, John, B.Sc., Shock, Blood Preservation. Asst. Professor of Surgery, Columbia Presbyterian Medical Center, New York, N. Y.

Serling, Maurice E., D.V.M., Veterinary Medicine. Owner of Small Animal Hospital, Larchmont, N. Y.

Seymour, Alpert, B.A., Parasitology. Graduate Student, Syracuse University, New York, N. Y.

Shanor, Leland, Ph.D., Mycology. Professor of Botany, University of Illinois, Urbana, Ill.

Shaver, John R., Ph.D., Embryology. Asst. Professor of Zoology, University of Missouri, Columbia, Mo.

Shoemaker, Richard N., Ph.D., Fermentation. Microbiologist, Chas. Pfizer & Co., Brooklyn, N. Y.

Shpuntoff, William, D.D.S., Dental Bacteriology. Private Practice, New York, N. Y.

Simmons, Leo W., Ph.D., Anthropology. Professor of Sociology, Yale University, New Haven, Conn.

Smith, Samuel Greger, Biochemistry, Biology. Research Chemist, Ridgewood, N. J.

Spurr, Gerald Baxter, B.S., Physiology. Student, Somerville, Mass.

Sterling, Joseph R., D.V.M., Veterinary Medicine. Owner of Dog & Cat Hospital, New York, N. Y.

Storm, Jack, B.A., Cellular Physiology, Biochemistry. Fellowship, Brooklyn College, Brooklyn, N. Y.

Storr, John F., Biology. Adelphi College, Garden City, L. I., N. Y.

Strauss, Maurice J., M.D., Dermatology. Clinical Professor of Dermatology, Yale University, New Haven, Conn.

Taft, Edgar B., M.D., Pathology, Histochemistry. Research Fellow in Medicine, Collis P. Huntington Memorial Hospital, Harvard University, Cambridge, Mass.

Taggart, S. Ross, M.D., Venereal Disease. Director, Bureau of Venereal Disease, D. C. Health Dept., Washington, D. C.

Tahmisian, Theodore Newton, Ph.D., Biology. Group Leader, Assoc. Scientist, Division of Biology and Medicine, Argonne National Laboratory, Chicago, Ill.

Teague, Robert S., Ph.D., Pharmacology. Professor & Chairman, Dept. of Pharmacology, Medical College of Alabama, Birmingham, Ala.

Toch, Rudolf, M.D., Pediatric Cancer, Children's Cancer Research Foundation, Boston, Mass.

Travis, John H., Mental Hygiene. Superintendent, Manhattan State Hospital, New York, N. Y.

Treadwell, Carleton R., Ph.D., Biochemistry. Assoc. Professor of Biochemistry, George Washington University, Washington, D. C.

Troy, Mathew A., D.V.M., Veterinary Medicine. Owner & Chief Veterinarian of Animal Hospital, Pelham, New York, N. Y.

Troy, William P., B.S., Cytology. Biologist, Lederle Laboratories, Pearl River, N. Y.

Turner, Robert Arnold, Ph.D., Biochemistry. Asst. Professor of Biochemistry, State University, New York, Brooklyn, N. Y.

Van Griffis, Le, Ph.D., Theoretical & Applied Mechanics. Manager, Division of Engineering Mechanics Research, Armour Research Foundation, Chicago, Ill.

Vera, Harriette D., Ph.D., Culture Media for Bacteria. Research Bacteriologist, Baltimore Biological Laboratory, Baltimore, Md.

Walton, Robert Greenwood, B.S., Dermatology. Asst. Research, Dermatology, Stanford University Hospitals, San Francisco, Calif.

Wislocki, George B., M.D., Anatomy. Professor of Anatomy, Harvard Medical School, Boston, Mass.

Zaugg, Harold E., Ph.D., Organic Medicine, Chemistry. Research Chemist, Abbott Laboratories, North Chicago, Ill.

STUDENT MEMBERSHIP

Brod, Morton S., B.A., Biology. Student, Columbia University, New York, N. Y.

Perr, Mortimer H., B.S., Dental Student, New York University, New York, N. Y.

C. Elected August 15, 1951

LIFE MEMBERSHIP

Moran, Jr., Eugene F., N.A., Mar. Eng., Oceanography, Mathematics, Engineering. Vice-President, Moran Towing Co., New York, N. Y.

Sloan, Jr., Alfred P., D.Sc., LL.D., Cancer. Chairman of Board, General Motors Corp., New York, N. Y.

Wallerstein, Harry, M.D., Hematology. Hematologist, Jewish Memorial Hospital, New York, N. Y.

SUSTAINING MEMBERSHIP

Coakley, Walter A., M.D., F.A.C.S., Brooklyn, N. Y.

Forsyth, Bruce D., D.D.S., Dentistry. Asst. Surgeon General, Chief Dental Officer, U. S. Public Health Service, Washington, D. C.

Gilbert, Sydney S., Hair, Scalp. President, Parker Herbex Co., Stamford, Conn.

Goubeaud, Charles J., D.V.M., Veterinary Medicine. Private Practice, Bayside, L. I., N. Y.

Groten, Harris H., D.V.M., Biology. Private Veterinary Practice, Hempstead, L. I., N. Y.

Hansen, James L., M.D., Biology, Pathology. Director & Commanding Officer, First Army Area Medical Laboratory, New York, N. Y.

Jensen, D. Rees, M.D., Peripheral Vascular Diseases. Asst. Professor of Clinical Surgery, Cornell University, New York, N. Y.

Kalberg, Victor N., Chemistry of Fungicides. Technical Director, Scientific Oil Compounding Co., Chicago, Ill.

Knox, James M., B.A., Vice-President, Research Corporation, New York, N. Y.

Lang, Harry B., M.B., Psychiatry. Asst. Commissioner and Assoc. Professor of Psychiatry, Albany Medical School, Albany, N. Y.

Lapin, Lyon, M.D., Internal Medicine. Private Practice, Montreal, Canada.

May, Robert E., D.V.M., Veterinary Medicine. Private Practice, Greenvale, L. I., N. Y.

Schapiro, Mark M., M.D., Medicine, Surgery. Consulting Surgeon, Hospital General San Felipe, Tegucigalpa, D. C., Honduras.

Sealock, Robert R., Ph.D., Biochemistry. Professor of Chemistry, Iowa State College, Ames, Iowa.

Sirgel, Morris, D.V.M., Veterinary Medicine. Private Practice, Nyack, N. Y.

Veitch, Jr., Fletcher P., Ph.D., Biochemistry. Assoc.

Professor of Biochemistry, University of Maryland, College Park, Md.

Wallach, Robert, M.D., Medicine. Professor of Medicine, New York Polyclinic Medical School, New York, N. Y.

Weil, Ruth A., Ph.D., Organic Chemistry. President & Research Worker, Hickrill Chemical Research Foundation, Katonah, N. Y.

Zerfas, Leon G., M.D., Medicine. Biochemistry. Biochemical Research, Camby, Ind.

ACTIVE MEMBERSHIP

Aldrich, Robert A., M.D., Medicine. Asst. Professor of Pediatrics, University of Oregon, Portland, Ore.

Alexander, Benjamin, M.D., Hematology. Asst. Professor, Harvard Medical School, Boston, Mass.

Amos, Franklyn B., M.D., Medicine. Director, Professional Training, New York State Dept. of Health, Albany, N. Y.

Artz, Curtis P., M.D., Surgery. Assoc. Surgeon, Brook Army Hospital, Fort Sam Houston, Tex.

Barnett, E. Dwight, M.D., Med. Administrative Director of Harper Hospital, Detroit, Mich.

Bedoukian, Paul Z., Ph.D., Terpenes. Chemist, Compagnie Parento Inc., Croton-on-Hudson, N. Y.

Belgorod, Samuel H., M.D., Medicine. Assoc. Visiting Physician, Sea View Hospital, New York, N. Y.

Blain, Donald G., M.D., Surgery. Intern, Union Memorial Hospital, Baltimore, Md.

Blanford, Charles J., Ph.D., Agricultural Economics. Market Administrator, N. Y. Metropolitan Milk Marketing Area, New York, N. Y.

Blaufox, Norman Henry, Mathematics. New York, N. Y.

Britt, Eugene M., M.S., Microbiology. Assoc. Research Bacteriologist, Miles Research Laboratories, Elkhart, Ind.

Browe, John H., M.D., Human Nutrition. Director, Bureau of Nutrition, N. Y. State Dept. of Health, Albany, N. Y.

Brown, Earl H., D.V.M., Pharmacology. Instructor, Tuskegee Institute, Ala.

Brown, George Francis, M.S., Protozoology, Biochemistry. Teacher, Ozone Park, L. I., N. Y.

Brumfield, Jr., William A., M.D., Epidemiology. First Deputy Commissioner, New York Dept. of Health, Delmar, N. Y.

Callaway, Jasper L., M.D., Dermatology. Professor of Dermatology, Duke University, Durham, N. C.

Cesare, Perri Gulio, Biochemistry. Research Fellow, Sloan Kettering Institute, N. Y.

Cluxton, Jr, M.D., Metabolic Diseases. Director of Medical Research, Armour Laboratories, Chicago, Ill.

Cooper, George T., B.S., Engineering. Chemical Engineer, Rutherford, N. J.

Cullman, Howard S., L.L.D., Public Service. Chairman, New York Port Authority, New York, N. Y.

De Boer, Benjamin, Ph.D., Pharmacology. Professor of Pharmacology, University of North Dakota, Grand Forks, N. D.

De Mello, Lopo, M.D., Medicine, Syphilis. Asst. Clinical Professor of Dermatology, New York University, New York, N. Y.

Ebbs, J. Harry, M.D., Children's Medicine. Senior Staff Physician. Asst. Professor of Pediatrics, University of Toronto, Canada.

Eisenmenger, William J., M.D., Hepatic Disease. Associate, Rockefeller Institute, New York, N. Y.

Entwisle, George, M.D., Internal Medicine. Asst. Resident in Medicine, Evans Memorial Hospital, Boston, Mass.

Fenichel, Richard Lee, M.S., Biochemistry. Biochemical Research, Chrysler Corp., Detroit, Mich.

Finkelstein, Isidore S., Biophysics. Associate in Optometry, Columbia University, New York, N. Y.

Fish, Charles H., M.D., Surgery. Senior Surgeon, U.S.P.H.S., New York, N. Y.

Foldes, Francis Ferenc, M.D., Anesthesiology. Director of Anesthesia, Mercy Hospital, Pittsburgh, Pa.

Fourman, Victor G., Ph.D., Chemistry. President, Syntomatic Corp., New York, N. Y.

Gelter, Clyde W., M.D., Medical Research. Medical Director & Vice-President, Geo. A. Breon & Co., New York, N. Y.

Gillmeier, John A., Electromyography. Research Analyst, Reciprocator Laboratories, Newark, N. J.

Granzer, Roderick A., B.S., Medicine. Student, Georgetown University, Washington, D. C.

Grodman, Benjamin, Director, Dept. of Purchase, Central Testing Laboratory, City of New York, New York, N. Y.

Gruenberg, Ernest M., M.D., Public Health Psychiatry. Executive Director, New York State Mental Health Commission, Syracuse, N. Y.

Hartley, Carl, Ph.D., Forest Tree Diseases. Principal Pathologist, U. S. Bureau of Plant Industry, Beltsville, Md.

Havrilla, Raymond A., M.D., Dermatology. Dermatologist, New York, N. Y.

Herchenroeder, Francis L., D.V.M., Veterinary Medicine. Inspector in Charge, Port of N. Y. International Inspection & Quarantine, U. S. Dept. of Agriculture, New York, N. Y.

Idyll, Clifton P., M.A., Chemistry. Asst. Professor of Chemistry, Adelphi College, Garden City, L. I., N. Y.

Katz, Jacob S., L.L.B., Engineering, Mathematics. Chief Engineer, Police Dept., New York, N. Y.

Keutmann, E. Henry, M.D., Endocrinology, Metabolism. Asst. Professor of Medicine, University of Rochester, Rochester, N. Y.

Kingsley, Joyce W., M.D., Internal Medicine. Physician in Chief, The Alexander Blain Hospital, Detroit, Mich.

Klomme, Dorothea E., Ph.D. Microbiological Deterioration of Textiles. Chemist, Biological Deterioration Lab., Chemistry Div., Naval Res. Lab., Washington, D. C.

Kohler, Charles E., B.Sc., Biology. Regional Consultant, Insect & Rodent Control, U. S. Public Health Service, Denver, Col.

Krantz, Bernard, B.A., Mycology. Mycologist, General Cable Corp., Bayonne, N. J.

Langley, Leroy L., Physiology. Dept. of Physiology, Medical College Alabama, Birmingham, Ala.

Ledingham, George A., Ph.D., Mycology, Microbiology. Director, Prairie Regional Laboratory, National Research Council of Canada, Saskatoon, Canada.

Leibiger, Irma S., Physics. Director of Research, O. W. Leibiger Research Laboratories, Inc., Petersburgh, N. Y.

Lilly, Virgil Greene, Ph.D., Physiology. Professor of Physiology, Dept. of Plant Pathology, West Virginia University, Morgantown, West Va.

Loewy, Erich H., B.A., Medicine, Biology. Medical Student, Syracuse, N. Y.

Mendoza, Julian R., M.D., Urology. Medical Supervisor, Dept. of Health, Philippines.

Metraux, Rhoda, Ph.D., Anthropology. Columbia

University, Research in Contemporary Cultures, New York, N. Y.
Miller, Shefford S., D.V.M., Veterinary Medicine. Veterinarian Practitioner, Larchmont, N. Y.
Morrison, Harlan B., M.Sc., Antibiotic Research. Assistant Mycologist, Wyeth Inc., West Chester, Pa.
Mrak, E. M., Ph.D., Food Technology, Mycology. Division of Food Technology, University of California, Davis, Calif.
Muhler, Joseph C., D.D.S., Ph.D. Dental Research Assistant, Professor Dentistry, Indiana University, Bloomington, Ind.
Owen, Emily M., M.S., Microbiology. Bacteriologist, Colgate-Palmolive Peet Co., Jersey City, N. J.
Prince, Alton E., B.S., M.S., Mycology. Chief, Fungus Control Unit, Wright Air Development Center, Dayton, Ohio.
Quigley, J. P., Ph.D., Physiology. Chief, Division of Physiology.
Rebstock, Mildred C., Ph.D., Organic Biochemistry. Research Chemist, Parke, Davis & Co., Detroit, Mich.
Reid, Roger D., Ph.D., Microbiology. Head, Microbiology Branch, Office of Naval Research, Washington, D. C.
Revici, Emanuel, M.D., Biology. Scientific Director of the Institute of Applied Biology.
Riddell, J. M., M.D., Biology, Mycology. Assistant in Dermatology, University of Illinois, Chicago, Ill.
Sacks, Hyman J., D.V.M., Veterinary Medicine. Private Practice, Forest Hills, L.I., N. Y.
Sakal, E. H., Chemistry. Senior Scientist, Werner Institute for Therapeutic Research, New York, N. Y.
Salzberg, Harold E., Ph.D., Chemistry. Section Chief, Research Laboratory, The Borden Co., Chemical Division, Bainbridge, N. Y.
Schmitz, Walter A., M.D., Medicine, Psychiatry. Senior Director, Middletown State Homeopathic Hospital, Middletown, N. Y.
Scripps, Robert W., Agriculture, Horticulture, Geology. Vice-President Avon Industries, Owner, Young Eden Farm Orchard, Lake Orion, Mich.
Sells, Charles H., B.S., Civil Engineering. Consulting Engineer, New York, N. Y.
Shambora, William E., M.D., Medicine. Chief Surgeon, First Army, New York, N. Y.
Simons, Joseph H., Ph.D., Chemistry, Physics, Engineering. Co-ordinator of Fluorine Research, Professor of Chemical Engineering, University of Florida, Gainesville, Fla.
Sweet, J. D., D.V.M., Virus Diseases. Private Practice, Chateaugay, N. Y.
Tabor, Celia W., M. D., Medical Research Clinical Instructor in Medicine, George Washington University, Washington, D. C.
Tennent, David M., Ph.D., Biochemistry. Research Associate, Merck Institute for Therapeutic Research, Rahway, N. J.
Terry, Daniel H., Ph.D., Chemistry. Head of Tech. Service, Development and promotion of industrial surfactants, Antara Tech. Dept., Division of Gen. Dyestuff Corp., New York, N. Y.
Thomas, McCalip J., Ph.D., Chemistry. Assistant to Manager of Market Development, A. E. Staley Mfg. Co., Decatur, Ill.
Underwood, George R., M.D., Biology, Medicine. Medical Director, Smith, Dorsey Co., Lincoln, Neb.
Van Campen, M. G., Medical Chemistry. Head, Organic Dept., The W. S. Merrell Co., Research Laboratories, Cincinnati, Ohio.
Vandow, Eva S., M.D., Medicine. Medical Superintendent, Willard Parker Hospital, New York, N. Y.
Van Pernis, Paul A., M.D., Medical Mycology. Director of Laboratories, Swedish-American Hospital, Rockford, Ill.
Visscher, Frank E., Ph.D., Physiology. Pharmacologist, The Upjohn Co., Kalamazoo, Mich.
Vivino, A. Earl, Ph.D., M.D., Biochemistry, Nutrition. Instructor in Medicine, Georgetown University, Washington, D. C.
Volkin, Elliot, Ph.D., Biochemistry. Senior Biochemist, Oak Ridge National Laboratories, Oak Ridge, Tenn.
Wachstein, Max, M.D., Experimental Pathology. Director of Laboratories, Dept. of Pathology, St. Catherine's Hospital, Brooklyn, N. Y.
Wachtel, Curt S., M.D., Psychomatic Medicine. New York, N. Y.
Wagner, Robert M., Ph.D., Physical Organic Chemistry. Research Organic Chemist, General Electric Co., Richland, Wash.
Walmer, C. Richard, M.D., Industrial Medicine. Managing Director, Industrial Hygiene Foundation, Mellon Institute, Pittsburgh, Pa.
Wanderman, Sidney E., M.D., Medicine. Asst. Visiting Surgeon, N. Y. Cancer Institute, New York, N. Y.
Ward, Richard S., M.D., Pediatrics, Psychiatry, Psychology. Research Psychiatric Institute, New York, N. Y.
Ward, Walter E., M.D., Medical Biology. Medical Director, Cutter Laboratories, Berkeley, Calif.
Warner, George L., M.D.C.M., Psychiatry. Acting Director, Marcy State Hospital, Marcy, N. Y.
Warshaw, Leon J., M.D., Biology. Assoc. Attending Physician, Beth Israel Hospital, New York, N. Y.
Werner, Harold W., Ph.D. Biology. Director, Scientific Laboratories, The Wm. S. Merrell Co., Cincinnati, Ohio.
West, Louis Jolyon, M.D., Neurology, Psychiatry, Psychology. First Asst. Resident Psychiatrist, N. Y. Hospital, New York, N. Y.
Whitcomb, Gordon P., Ph.D., Organic Chemistry. Asst. Personnel Director, American Cyanamid Co., New York, N. Y.
Williams, Jonathan, W., Ph.D., Organic Chemistry. Manager, Biological Chemical Section, Grasselli Chemicals Dept., du Pont Co., Wilmington, Del.
Wilson, Charles P., M.D., Psychology. Private Practice, Psychiatry, New York, N. Y.
Wingard, Christian, M.D., Pharmacology. Research Fellowship, National Institute of Health, Public Health Service, Dept. of Pharmacology, Medical College of Alabama, Birmingham, Ala.
Winter, Irwin C., M.D., Ph.D., Internal Medicine, Director of Clinical Research, G. D. Searle & Co., Chicago, Ill.
Wirth, John C., Ph.D., Chemical Activities of Fungi. Asst. Professor of Chemistry, St. John's University, Brooklyn, N. Y.
Witten, Victor H., M.D., Dermatology. Assistant in Dermatology, University Hospital, N. Y. University Bellevue Medical Center, New York, N. Y.
Wolf, Bernard S., M.D., Radiology. Chief, Dept. of Radiology, Mt. Sinai Hospital New York, N. Y.
Wolnak, Bernard, Ph.D., Biochemistry. Research Chemist, Miner Laboratories, Chicago, Ill.
Yamasaki, Ken, M.D., Surgery. Resident Surgeon, Alexander Blain Hospital, Detroit, Mich.
Yoslow, Wilfred, M.D., Orthopedic & Traumatic Surgery. Visiting Orthopedic Surgeon, Gouverneur Hospital, New York, N. Y.

Young, Raymond M., Ph.D., Medical Microbiology. Research Bacteriologist, Institute of Pathology, Rhode Island Hospital, Providence, R. I.
Zienty, Mitchell F.. Ph.D. Synthetic Drugs. Research Chemist, Elkhart, Ind.
Zill, Leonard P., Ph.D., Biochemistry. Assoc. Biochemist, Oak Ridge National Laboratories, Oak Ridge, Tenn.
Zurmuhlen, Frederick H., Engineering. Commissioner, Dept. of Public Works, City of N. Y., New York, N. Y.

STUDENT MEMBERSHIP

Berritto, Carmela, Geology. Student, New York University, New York, N. Y.
Blaik, Maurice, B. A., Graduate Student, New York University, New York, N. Y.
Fein, Shirley, B. A., Science. Student, Hunter College, New York, N. Y.
Rudin, Cyril A., B.A., Micropaleontology, Geology. Graduate Student, New York University, New York, N. Y.
Ruskin, Asa Paul, B.A., Cell Physiology. Candidate for M.S., Brooklyn College, Brooklyn, N. Y.

D. Elected September 14, 1951

LIFE MEMBERSHIP

Thomas, John Oglesby, Ph.D., Biochemistry, Pharmacology. Section Leader, Cutter Laboratories, Berkeley, Calif.

SUSTAINING MEMBERSHIP

Brozen, Benjamin A., B.S., Endocrinology. Osteopathic Physician & Surgeon, Brooklyn, N. Y.
Dart, Justin W., President, Rexall Drug Co., Los Angeles, Calif.
Gotthelf, Ted, Pharmaceutical Ads. President, Ted Gotthelf Inc., New York, N. Y.
Jenney, John A., M.D., Surgery. Surgeon, New York, N. Y.
Joffe, Sarah, M.D., Medicine. Assoc. Anesthetist, Beth Israel Hospital, New York, N. Y.
Melhus, Irving E., Ph.D., Biology. Director, Iowa State College, Guatemala Tropical Research Center, Antigua, Guatemala.
Reheis, Daniel H., Chemistry. President, Reheis Co., Berkeley Heights, N. J.
Spiegel, B. Edgar, M.D., Allergy, Immunology. New York, N. Y.
Stock, Richard J., M.D., Internal Medicine. Asst. Physician in Medicine, Presbyterian Hospital, New York, N. Y.
Tarr, Leonard, M.D., Biology, Medicine. Assoc. Physician, Montefiore Hospital, New York, N. Y.
Wenger, H. Leslie, M. D., Medicine. Experimental Surgery, University Hospital, New York, N. Y.
Wheeler, Charles H., M.D., Medicine. Assist. Professor of Clinical Medicine, Cornell Medical College, New York, N. Y.
Whitmore, Willet F., M.D., Biology. Asst. Professor of Clinical Surgery, Cornell University Medical College, New York, N. Y.
Wolcott, Charles C., M.D., Endoscopy. Private Practice, Bronxville, N. Y.
Zimmering, Paul, M.D., Psychiatry, Psychology. Senior Psychiatrist, Bellevue Hospital, New York, N. Y.

ACTIVE MEMBERSHIP

Baldor, Julian F., M.D., Leukemias. Director, Palma Ceia Hospital, Tampa, Fla.
Bates, Philip K., Medicinal ,Products. President, Riker Laboratories, Inc., Los Angeles, Calif.
Beck, Ivan Thomas, Pharmacology. M.D., Lecturer, Dept. of Pharmacology, McGill University, Montreal, Canada.
Beerman, Herman, D.Sc., Dermatology, Syphilology. Philadelphia, Pa.
Beiser, Arthur, B. A., Physics, Research Assistant, New York University, New York, N. Y.
Brown, Frederick R., M.D., Medicine, Allergy. Clinical Instructor, New York University, New York, N. Y.
Cataldi, Rina C., B.S., Virology. Supervisor, Biological Manufacturing, E. R. Squibb & Sons, New Brunswick, N. J.
Compton, Walter Ames, M.D., Pharmacology. Vice-President, Miles Laboratories, Inc., & Ames Co. Inc., Elkhart, Ind.
Denny, Jr., Floyd W., M.D., Rheumatic Fever. Asst. Director, Streptococcal Diseases Laboratory, Warren Air Force Base, Wyo.
Foster, Morris, Ph.D. Physiological Genetics. Postdoctorate Research Fellow, National Cancer Institute, U. S. Public Health Service, Chicago, Ill.
Goldstein, Solomon N., Microbiology. Bacteriologist. Emulsal Corp., Chicago, Ill.
Hewitt, Gerald, M.D., Medicine, Psychology. Psychiatrist, Kings County Hospital Brooklyn, N. Y.
Hoff, Ebbe Curtis, Neurophysiology. Professor of Neurological Science, Medical College of Virginia, Richmond, Va.
Huddlestone, Jean, M.D., Medicine. Private Practice, New York, N. Y.
Israel, Martin, M.D., Medicine. Physician, New York, N. Y.
Jacobson, Jacob, M.D., Pathology. N. Y. Polyclinic Medical School & Hospital, New York, N. Y.
Japhe, Nathaniel M., M.D., Medical Sciences. Consultant for Insurance Companies and Attorneys, New York, N. Y.
Jeannopoulos, C. L., M.D., Orthopedic Surgery, Anatomy. Instructor in Orthopedic Surgery, N. Y. University Bellevue Hospital, New York, N. Y.
Jedwabnik, David F., M.D., Medicine. New York, N. Y.
Jennings, Elmer, R., M.D., Pathology. Asst. Professor of Pathology, Wayne University, Detroit, Mich.
Jimenez, Juan M., M.D., Radiology. Chief Roentgenologist, St. Mary's Hospital, Hoboken, N. J.
Johnson, Artell, E., M.D., Biology. New York, N. Y.
Jungmann, Martin, M.D., Engineering Problems in Medicine. Private Practice, New York, N. Y.
Junker, Ralph D., M.D., Biology, Engineering. Third Asst., Resident, Dept. of Surgery, St. Luke's Hospital, New York, N. Y.
Jurasz, Antony T., M.D., Medicine, Surgery. Private Practice, New York, N. Y.
King, James P., M.D., Pediatrics. Resident, Tumor Therapy Service, Children's Medical Service, Boston, Mass.
Lascoff, Frederick D., Phar. D., Pharmacy. President, J. Leon Lascoff & Son, Inc., New York, N. Y.
Lauher, Frances Halo, M.T., R.N., Biology. Director of Laboratories, Leo N. Levi Memorial Hospital, Hot Springs, Ark.
Lawlis, Jr., John F., M.S., Biology. Asst. Parasi-

tologist, Eli Lilly Research Laboratory, Indianapolis, Ind.

Leutritz, Jr., John, Ph.D. Industrial Microbiology. Research Engineer, Bell Telephone Laboratory, Murray Hill, N. J.

Levy, Lydia, Mycology. Mycologist, Brooklyn, N. Y.

McCallan, S. E. A., Ph.D., Plant Pathology. Plant Pathologist, Yonkers, N. Y.

McCarran, Daniel, M.D., Dermatology. Resident, Dept. of Dermatology, Melrose Hospital, New York, N. Y.

McMahon, Rita M., M.S., Biology. Graduate Asst. in Biology, Fordham University, New York, N. Y.

Marrow, Charles Taylor, M.D., Internal Medicine. Lt. U.S.N., Lake Forest, Ill.

Mohr, Milton E., B.S., E.E., Electronic Control. Head of Computer Research, & Development Laboratory, Hughes Aircraft Co., Culver City, Calif.

Monnier, Jacques J., M.D., Infectious Diseases, Antibiotics. Asst. Institute de Bacteriologie, Toulouse, France.

Nippell, Robert M., M.S., Biochemistry. Research Fellow, Dept. of Biochemistry, University of Southern California, Los Angeles, Calif.

Palmaccio, Joseph, M.S., Microbiology. Microbiologist, E. R. Squibb & Sons, New Brunswick, N. J.

Perrin, Eugene V., B.A., Pharmacology. Research Assistant, Pharmacology Dept., University of Michigan, Ann Arbor, Mich

Petty, Charles S., M.D., Pathology, Physiology. House Staff, M.I.B.H. Hospital, Cooperstown, N. Y.

Pinck, Bernard D., M.D., Urology. Urologist, Asst. Clinical Professor of Urology, New York University, New York, N. Y.

Schmidt, R. Marilyn, B.S., Medical Research. Medical Student, Woman's Medical College of Pennsylvania.

Shidlovsky, Boris Alex., B.A., Bacteriology. Bacteriologist, C. Pfizer & Co. Brooklyn, N. Y.

Siegel, Benjamin V., Ph.D., Bacterial Physiology. Instructor of Bacteriology & Experimental Pathology, Stanford University, Stanford, Calif.

Siegmund, Otto Hans, D.V.M., Pharmacology. Veterinary Research, Merck & Co., Inc., Rahway, N. J.

Snell, George D., D.Sc., Genetics. Research Associate. R. B. Jackson Memorial Laboratory, Bar Harbor, Maine.

Speert, Harold, M.D., Physiology of Reproduction. Associate in Obstetrics & Gynecology, Columbia University, New York, N. Y.

Steinman, John Francis, M.D., Medicine. Lincoln, Neb.

Stetson, Jr., Chandler Alton, M.D., Immunology. Captain, USAR, Cheyenne, Wyo.

Talmage, Roy V., Ph.D. Biology. Assoc. Professor of Biology, Rice Institute, Houston, Tex.

Tennant, Robert, M.D., Pathology. Pathologist, Hartford, Conn.

Terzian, Levon A., D.Sc., Microbiology. Parasitologist, Naval Medical Research Institute, Bethesda, Md.

Tesoro, Giuliana C., Ph.D., Organic Chemistry. Head, Organic Synthesis Dept., Onyx Oil & Chemical Co., Jersey City, N. J.

Thomas, Walter William, Ph.D., Organic Chemistry. Research Chemist, Hercules Powder Co., Wilmington, Del.

Thomson, John F., Ph.D., Pharmacology, Biochemistry. Assoc. Pharmacologist, Argonne National Laboratory, Chicago, Ill.

Tint, Howard, Ph.D. Biochemistry. Senior Research Chemist, Wyeth Institute of Applied Biochemistry, Philadelphia, Pa.

Titus, Elwood O., Ph.D., Biochemistry. Chemist, National Institutes of Health, Bethesda, Md.

Todd, Charles W., Ph.D., Biology. Research Supervisor, Chemical Dept., E. I. du Pont de Nemours & Co., Wilmington, Del.

Tompkins, Paul C., Ph.D., Biochemistry. Scientific Director, U. S. Naval Radiological Defense Laboratory, San Francisco, Calif.

Toolan, James, M.D., Psychiatry. Junior Psychiatrist, Bellevue Hospital, New York, N. Y.

Tracy, Ralph L., Ph.D., Biological Chemistry. General Manager, Remsen Chemicals Inc., Oceanside, L. I., N. Y.

Traub, Eugene F., M.D., Dermatologic Research, Professor of Dermatology, New York Medical College, New York, N. Y.

Trickey, E. Bruce, Ph.D., Organic Chemistry. General Foreman, Claymont Development Laboratory, Claymont, Del.

Triebold, Howard O., Ph.D., Biochemistry. Professor of Agriculture & Biological Chemistry, The Pennsylvania State College, State College, Pa.

Tuttle, Esther, M.D., Prevention of Degenerative Diseases. Private Practice, New York, N. Y.

Wachtel, Louis W., Ph.D., Biochemistry. Research Division, The Upjohn Co., Kalamazoo, Mich.

Waddle, H. M., Ph.D. Organic Chemistry. Head, Chemistry Dept., Research Division, West Point Manufacturing Co., Shawmut, Ala.

Waldeck, William F., Ph.D., Chemical Research. Director of Chemical Research, Wyandotte Chemicals Corp., Wyandotte, Mich.

Wallace, Bruce, Ph.D., Population Genetics. Geneticist, The Biological Laboratory, Cold Spring Harbor, L. I., N. Y.

Wallis, G. Carroll, Ph.D., Animal Nutrition. Animal Nutritionist, Standard Brands Inc., New York, N. Y.

Wang, Mark Kai-Hsi, M.D., Medicine, Surgery. Instructor, Dept. of Surgery, Columbia University, New York, N. Y.

Warren, A. P., M.D., D.D.S., Medicine. Practicing Physician & Dentist, New York, N. Y.

Waterman, William B., M.D., Medicine. Private Practice, New York, N. Y.

Watson, William R., M.D., Pediatrics. Research Pediatrician, Babies Hospital, New York, N. Y.

Weidner, John Prestin, Ph.D., Paper Technical Superintendent, Container Corp. of America, Philadelphia, Pa.

Weiher, Leo, M.D., Hematology, Asst. Clinical Professor, New York University, New York, N. Y.

Weiner, Murray, M.D., Medical Research. Assistant in Medicine, New York University, College of Medicine, New York, N. Y.

Weingarten, Michael, M.D., Gastroenterology. Attending Gastroenterologist, Beth Israel Hospital, New York, N. Y.

Weinstein, May, M.D., Psychology. Junior Psychiatrist, Kings County Hospital, Brooklyn, N. Y.

Weiss, Samuel, D.Sc., Gastroenterology. Professor of Gastroenterology, N. Y. Polyclinic Medical School, New York, N. Y.

Weisz, Paul, M.D., Physiology, Biochemistry. Research Fellow, Montefiore Hospital, New York, N. Y.

Wells, Emery I., M.D., Psychosomatic Problems. Clinical Assistant in Psychiatry, Mt. Sinai Hospital, New York, N. Y.

Weinhart, Antonia, M.D., Psychoanalysis, New York, N. Y.
Wenseslas, Jardetzky, Ph.D., Mathematics, Engineering. Research Associate, Columbia University, New York, N. Y.
West, Harold D., Ph.D., Biochemistry. Professor of Biochemistry, Meharry Medical College, Nashville, Tenn.
Wheeler, Charles M., Ph.D. Medical Entomology. Chief Virus & Rickettsial Disease Research, Brea, Calif.
Whitaker, Joseph S., Ph.D., Organic High Polymers. Research Chemist, Bakelite Co., Bloomfield, N. J.
Whitlock, John H., D.V.M., Parasitology. Assoc. Professor of Parasitology, Cornell University, Ithaca, N. Y.
Wick, Arne N., Ph.D., Bio-chemical Research. In charge of Research Laboratory, at Scripps Metabolic Clinic, La Jolla, Calif.
Wilder, Joseph, M.D., Neurology, Endocrinology, Psychology. Private Practice, New York, N. Y.
Wilhelm, Hazel S., M.D., Medicine. Pediatrician, Private Practice, New York, N. Y.
Wilson, James L., M.D., General Surgery. Assoc. Visiting Physician, Harlem Hospital, New York, N. Y.
Wolberg, Lewis R., M.D., Medicine. New York, N. Y.
Wolf, Heinrich F., M.D., Physical Medicine. Retired, New York, N. Y.
Wolfe, Jr., Elwood K., B.A., Biology, Biometrics. Biologist, Biological Laboratories, Chemical Corps., U. S. A.
Wolff, James Alexander, M.D., Medicine. Instructor in Pediatrics, Columbia University, New York, N. Y.
Yerby, Alonzo S., M.D., Public Health. Assoc. Medical Director, Health Insurance Plan of N. Y., New York, N. Y.
Yohalem, Morton, M.D., Medicine. Physician, New York, N. Y.
Young, Henry, M.D., Medicine. Private Practice, New York, N. Y.
Zeckel, Adolf, M.D., Psychoanalysis, Biology. Psychoanalyst, Private Practice, New York, N. Y.
Zuckerman, Hyman, M.D., Medicine, New York, N. Y.

E. Elected October 25, 1951

LIFE MEMBERSHIP

Marti-Ibanez, Felix, M.D., Psychology, Anthropology, Editor, Washington Institute of Medicine, New York, N. Y.

SUSTAINING MEMBERSHIP

Aiken, Donald Neale, D.O., Biology, Anthropology. Anaesthetist, Carson City Hospital, Carson City, Mich.
Black, John B., M.D., Medicine, Surgery. Physician & Surgeon, Jacksonville, Fla.
Ferrara, John D., M.D., Science. Physician, Jacksonville, Fla.
Freed, Frederick C., M.D., Gynecology. Clinical Professor of Gynecology, New York University, New York, N. Y.
Jewett, Eugene Lyon, M.D., Orthopedic Surgery. Orthopedic Surgeon, Orlando, Fla.
Kaftal, Marcus, M.D., Medicine. Physician, New York, N. Y.
Kahn, Edward, M.D., Obstetrics, Gynecology. Asst. Visiting Obstetrician, Sydenham Hospital, New York, N. Y.
Lewis, Frances P., M.A., Biology. High School Teacher, New York, N. Y.
Lupton, Jr., Charles H., M.D., Pathology. Asst. Professor of Pathology, University of Virginia, Medical School, Charlottesville, Va.
Pringle, John A., Gynecology. Director, Gynecological Division, Julius Schmid Inc., Oakland, N. J.
Speed, Albert, M.D., Medicine. Private Practice, New York, N. Y.
Spillman, Ramsey, M.D., Medicine, Biology. Private Practice, New York, N. Y.
Spivack, Issac Don, M.D., Biology. Associate in Optometry, Columbia University, New York, N. Y.
Squire, Jack J., M.D., Obstetrics, Gynecology. Private Practice, New York, N. Y.
Stein, Aaron, M.D., Psychiatry. Private Practice, New York, N. Y.
Swanker, Wilson A., M.D., Biology. Plastic Surgeon, New York, N. Y.
Swartz, Harry, M.D., Allergy, Psychology. Clinical Assistant, Allergy Out-Patient Dept., Roosevelt Hospital, New York, N. Y.
Thompson, Frederick R., M.D., D.Sc., Orthopedic Surgery. Asst. Attending, St. Luke's Hospital, New York, N. Y.
Tobin, Louis H., M.D., Dermatology. Asst. Attending, University Hospital, New York, N. Y.
Tosteson, Daniel C., M.D., Physiology. Junior Physician, Brookhaven National Laboratories, Upton, L. I., N. Y.
Tyroler, Herman A., M.D., Biology, Medicine. Physician, U. S. Air Force.
Vicens, Cristobal A., M.D., Medicine, Metabolism. Chief, Diabetic Clinic, City Hospital, New York, N. Y.
Vlavianos, Simonide G., Ph.D., Anatomo-histopathologique Alterations of Cells in Psychoses, New York, N. Y.
Votos, Anthony S., M.D., Psychiatry, Medicine. Private Practice, New York, N. Y.
Winslow, T. Scudder, M.D., Surgery. Surgeon, The Roosevelt Hospital, New York, N. Y.

ACTIVE MEMBERSHIP

Akin, Benjamin A., Experimental Medicine. Medical Research Assistant, Miami, Fla.
Asheshov, Ignor, Bacteriology. Bacteriologist, New York Botanical Garden, New York, N. Y.
Barghoorn, Elso S., Ph.D., Paleobotany. Assoc. Professor of Botany, Harvard University, Cambridge, Mass.
Barnes, Thomas C., D.Sc., Pharmacology. Assoc. Professor of Pharmacology, Hahnemann Medical College, Philadelphia, Pa.
Battersby, William S., Ph.D., Psychophysiology. Psychophysiologist, The Mt. Sinai Hospital, New York, N. Y.
Ben, Max, B.A., Endocrinology. Graduate Student, Princeton University, Princeton, N. J.
Blumenkopf, Norman, B. A., Chemistry, Mycology. Patent Attorney, General Aniline & Film Corp., Washington, D. C.
Boehm, Alice E., Ph.D., Psychology. Independent Research, New York, N. Y.
Bougerolle, Albert, Ph.D., Aviation. Research Engineer, Clamont, France.
Breit, Gregory, Ph.D., Nuclear Physics. Professor of Physics, Yale University, New Haven, Conn.

Bridges, Alvin E., M.S., Microbiology, Mycology. Microbiologist, Ethicon Suture Laboratories, New Brunswick, N. J.

Brobeck, John R., M.D., Physiology. Assoc. Professor of Physiology, University of Pennsylvania, Philadelphia, Pa.

Brunst, Victor, V., Radiation Biology. Research Associate, University of Maryland, Baltimore, Md.

Busby, Esther B., B.A., Nutrition. Liaison Scientific Research.

Calman, Carl, M.D., Physiology. Asst. Professor of Physiology, Grand Forks, N. D.

Celander, David Robert, M.S., Biochemistry. Research Assistant, University of Iowa, Iowa City, Iowa.

Clymann, Martin J., M.D., Medicine, Biology. Biochemist, Hospital for Joint Diseases, Bellevue Medical Center, St. Clare's Hospital, New York, N. Y.

Cobb, Beatrix, M.S., Psychosomatic Medicine. Fellow in Psychology, M.D. Anderson Hospital, Houston, Tex.

Cohen, Sylvan Irving, Ph.D., Phytopathology. Technical Director, Gallowhur Chemical Corp., New York, N. Y.

Cole, Wilbur V., D. O., Neurohistology, Neurophysiology. Asst. Professor of Anatomy, Kansas City College of Osteopathy & Surgery, Kansas City, Mo.

Colter, John Sparby, Ph.D., Enzymology. Research Associate, American Cyanamid Co., Pearl River, N. Y.

Cox, John William, Physiology. Research Fellow, U. S. Public Health Service, St. Louis, Mo.

De Sanctis, Armand, M.S., Immunology, Biochemistry. Research Associate Sharp & Dohme, Chester, Pa.

De Yonker, John F., D.O., Psychology. Private Practice, Detroit, Mich.

Fink, Bernard Raymond, B.Sc., M.R.C.S., Anesthesiology. Senior Resident, Anesthesiology, Beth Israel Hospital, New York, N. Y.

Gaudet, E. Louise, Ph.D., Clinical Psychology. Clinical Psychologist, Veterans Administration Mental Hygiene Clinic, Newark, N. J.

Greenspan, Kalman, B.S., Pharmacology. Graduate Student, Brooklyn, N. Y.

Gross, Milton Michael, B.A., Basic Medical Research. Student, State University of New York, New York, N. Y.

Heiman, Marcel, M.D., Psychoanalysis. Private Practice, New York, N. Y.

Herrmann, George, D.Sc., Engineering. Professor, Columbia University, New York, N. Y.

Herskovitz, Selma, B.A., Experimental Psychology. Graduate Assistant, Experimental Psychology, Brooklyn College, New York, N. Y.

Hodgson, James G., Ph.D., International & Interinstitutional Cooperation. Director of Libraries, Colorado A. & M. College, Fort Collins, Colo.

Huesca-Mesia, Carlos, Chemistry, Physics. Head, Dept. of Chemistry, Institute of Applied Biology, Brooklyn, N. Y.

Irwin, Dudley Arthur, M.D., Industrial Medicine. Medical Director, Aluminum Co. of America, Pittsburgh, Pa.

Jolowicz, Ernst, M.D., Psychotherapy. Private Practice, Great Neck, L. I., N. Y.

Kahan, Edmund, M.D., Ophthalmology. Private Practice, New York, N. Y.

Kenny, Elizabeth, R.N., Poliomyelitis. Head, Sister Kenny Foundation, Minneapolis, Minn.

Klein, Samuel, D.Sc., Medical Chemistry. Medical Research, Newark, N. J.

Knowles, Harold S., B.S., M.D., Biology, Mycology. Private Practice, Orlando, Fla.

Koch, Alan, B.S., Pharmacology. Student, New York, N. Y.

Kraus, Frederick W., M.D., Dental Medicine. Research Associate, Tufts College Dental School, Boston, Mass.

Kreeger, Morris H., M.D., Hospital Administration. Executive Director, Michael Reese Hospital, Chicago, Ill.

Lenhoff, Howard M., B.A., Biochemistry. Junior Instructor, Biology, Johns Hopkins University, Baltimore, Md.

Leonard, Charles Arthur, M.Sc., Pharmacology. Graduate Student, Philadelphia College of Pharmacy & Science, Philadelphia, Pa.

Levine, Rachmiel, M.D., Endocrinology, Metabolism. Director, Dept. of Metabolism, Michael Reese Hospital, Chicago, Ill.

Leviticus, Rene, M.D., Dermatology. Asst. Attending, Bellevue Hospital, New York, N. Y.

Liberman, Leonard A., B.S., Biochemistry. Graduate Student, University of Rochester, Rochester, N. Y.

Lieberman, Murray, M.D., Medicine, Psychiatry. Resident in Psychiatry, Kings County Hospital.

Lucia, S. P., M.D., Medicine, Hematology. Professor of Medicine, University of California, San Francisco, Calif.

Ludwig, Bernard J., Ph.D., Medicinal Chemistry. Asst. Director, Research & Development, Carter Products, Inc., New Brunswick, N. J.

MacKay, E. M., Clinical Investigation, Endocrinology. Assoc. Medical Director, E. R. Squibb & Sons, New York, N. Y.

Malafatopoulos, Stavros, A., M.D., Medicine. Public Health Consultant to E.C.A. Mission to Greece, Athens, Greece.

Maxwell, Robert A., B.A., Biology. Graduate Student, Princeton University, Princeton, N. J.

Milzer, Albert, M.D., Virology, Medical Bacteriology. Director of Virology & Bacteriology, Michael Reese Hospital, Chicago, Illinois.

Moldave, Kivie, M.S., Biochemistry. Research Fellow, University of Southern California, Los Angeles, Calif.

Moss, Melvin Lionel, D.D.S., Anatomy. Fellow in Anatomy, Columbia University, New York, N. Y.

Munemitsu, Saylo, M.S., Endocrinology. Graduate Research Assistant, The State University of Iowa, Iowa City, Iowa.

Nicholson, Jr., Samuel T., M.D., Industrial Medicine. Medical Director, Doehler Jarvis Corp., Pottstown, Pa.

Olive, L. S., Ph.D., Mycology. Professor of Mycology, Columbia University, New York, N. Y.

Pepper, Rollin E., B.A., Bacteriology. Microbiologist, Ethicon Suture Laboratories, New Brunswick, N. J.

Perrone, Joao C., M.A., Biochemistry. Research Chemist, Inst. Nacional de Technologia, Rio de Janeiro, Brazil.

Revivi, E. Fanita, B.S., Physiology. Research Assistant, Institute of Applied Biology, Brooklyn, N. Y.

Richter, Friedrich, Ph.D., Organic Chemistry. Director of Beilstein Institute, Frankfort on the Main, Germany.

Rochlin, Isidore, M.D., Medicine. Senior Research Fellow, Rush Department of Medicine, Presbyterian Hospital, Chicago, Ill.

Rosenhaugh, Edmund Carter, M.D., Ophthalmology. Ophthalomogist, Workmen's Compensation Board, New York, N. Y.
Saletan, Leonard T., M.A., Chemistry. Chemist, Wallerstein Laboratories, New York, N. Y.
Schwartz, Donald M., B.S., Chemistry. Inspector, Chemical Corp., Brooklyn, N. Y.
Shimenovitz, Martin, B.A., Medicine. Student, Syracuse University, Syracuse, N. Y.
Smith, Euclid M., M.D., General Internal Medicine. Physician, Hot Springs, Ark.
Spencer, Gerald A., M.D., Dermatology. Instructor, New York University, Bellevue Medical Center, New York, N. Y.
Spiegelman, Anna R., M.D., Medicine. Private Practice, New York, N. Y.
Speilman, Morton M., M.D., Medicine. New York, N. Y.
Sporer, Andrew, M.D., Urology. Instructor in Urology, New York Polyclinic Hospital, New York, N. Y.
Stanton, Edward Fuller, M.D., Medicine. Private Practice, New York, N. Y.
Staphen, Manuel, M.D., Psychology. Private Practice, New York, N. Y.
Stein, Paul, M.D., Medicine. Associate in Medicine, City Hospital, New York, N. Y.
Stern, Rudolf A., M.D., Internal Medicine. Associate Physician, City Hospital, New York, N. Y.
Stone, Samuel, M.D., Pulmonary Disease in Pediatrics. Asst. Clinical Professor of Pediatrics, New York University College of Medicine, New York, N. Y.
Strax, Philip, M.D., Medicine. Attending Roentgenologist, Bellevue Hospital, New York, N. Y.
Strax, Selig, M.D., Medicine, Surgery. Assoc. Visiting Surgeon, Harlem Hospital, New York, N. Y.
Sudimack, Jr., Joseph, B.A., Bacteriology. Graduate Assistant, Ohio State University, Columbus, Ohio.
Sutro, Charles J., M.D., Endocrinology. Assoc. Orthopedic Surgeon, Hospital for Joint Diseases, New York, N. Y.
Swenson, Paul A., Physiology. Instructor in Zoology, University of Massachusetts, Amherst, Mass.
Tabhat, Samuel F., M.D., Psychiatry. Associate, Hillside Hospital, New York, N. Y.
Teichner, Herbert, M.D., Biology. Assoc. Visiting Obstetrician and Gynecologist, Metropolitan Hospital, New York N. Y.
Termer, Franz, Ph.D., Ethnology, Anthropology. Professor of Ethnology & Director of Hamburgusches Museum, Hamburg, Germany.
Timasheff, Serg N., Ph.D., Protein Physical Chemistry. Research Fellow, Chemistry Dept., Yale University, New Haven, Conn.
Townsley, Harry E., D.O., Metabolic Medicine. Physician, Kirksville, Mo.
Trautman, Edgar Charles, M.D., Neurology, Psychiatry. Assoc. Attending, Neuro-psychiatrist, Lincoln Hospital, New York, N. Y.
Tria, Eusebio, Ph.D., M.D., Biochemistry. Professor of General Physiology, University of Ferrara, Ferrara, Italy.
Tuck, L. Dallas, Ph.D., Physics, Chemistry. Asst. Professor of Chemistry, University of California, Medical Center, San Francisco, Calif.
Tulin, Maurice, M.D., Medicine. Instructor in Medicine, Cornell University Medical College, New York, N. Y.
Van Roekel, Henry, Ph.D., D.V.M., Animal Diseases. Research Professor, Dept. of Veterinary Science, University of Massachusetts, Amherst, Mass.
Veres, Michael, Ph.D., Chlorophyll. Research Chemist, Airkem, Inc., New York, N. Y.
Voohees, Irving Wilson, M.D., Medicine. Assoc. Professor, College of Physicians & Surgeons, Columbia University, New York, N. Y.
Warshaw, Thelma G., M.D., Dermatology. Research Fellow, Skin & Cancer Unit, New York University, Bellevue Hospital, New York, N. Y.
Webber, Harold H., Ph.D., Textiles. Executive Director, Lowell Textile Institute Research Foundation, Lowell, Mass.
Weisner, Wayne M., M.D., Medicine. U. S. Army.
Weiss, A. Kurt, M.S., Metabolism. Graduate Student in Physiology, University of Rochester, Rochester, N. Y.
Weisshaus, Stanley Z., M.D., Medicine. Private Practice, New York, N. Y.
Wenger, Byron S., Ph.D., M.S., Embryology. Asst. Professor of Anatomy, University of Kansas, Lawrence, Kans.
White, Jack Edward, M.D., Surgery, Cancer. Asst. Professor of Surgery, Harvard University Medical School.
Whitten, William W., M.D., Medicine. Private Practice, Pediatrics, New York, N. Y.
Wiener, Roslyn, M.D., Endocrinology. Volunteer Worker in Dept. of Therapeutics, New York University Medical School, New York, N. Y.
Wilkins, Robert Wallace, M.D., Cardiovascular Physiology. Assoc. Professor of Medicine, Boston University School of Medicine, Boston, Mass.
Winkler, Franz E., M.D., Psychology, Medicine. Private Practice, New York, N. Y.
Wolf, Maurice E., M.D., Medicine, Biology. Chief, Arthritis Dept., Mt. Sinai Hospital, New York, N. Y.
Zerbe, Richard O., M.S., Chemistry. Research Chemist, Rubber Service Dept., Monsanto Chemical Co., Nitro, West Va.

STUDENT MEMBERSHIP

Braswell, Emory, Chemistry. Student, Brooklyn Polytechnic Institute, Brooklyn, N. Y.
Kallos, Andrew, Mycology. Student in Dermatology, New York Polyclinic, New York, N. Y.
Walcott, S. Alexander, Psychiatry. Student, New York University, New York, N. Y.
Waldman, Ruth M., Speech Correction. Student, Brooklyn College, Brooklyn, N. Y.
Wilsey, John Colver, Surgery. Student, First Columbia Surgical Division, Bellevue Hospital, New York, N. Y.

F. Transferred to Life Membership October 19, 1949

LIFE MEMBERSHIP

Freedman, Louis, M.S., Ph.D., Biochemistry. Vice-President in Charge of Research, U. S. Vitamin Corp.

DO NOT CIRCULATE